National Agricultural Research Systems In Asia

Edited by ALBERT H. MOSEMAN

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ABOUT THE EDITOR

Dr. Moseman, an Associate of the Agricultural Development Council, has been concerned with the organisation and administration of agricultural research for more than 25 years. He served as Chief of the Bureau of Plant Industry, Soils and Agricultural Engineering, and as Director of Crops Research in the U.S. Department of Agriculture prior to joining the Rockefeller Foundation in 1956. He was Director of the Foundation's programme in Agricultural Sciences from 1960 to 1965, when he was appointed Assistant Administrator for Technical Cooperation and Research in the U.S. Agency for International Development.

Since joining the Agricultural Development Council in 1967 Dr. Moseman has given special attention to factors involved in strengthening national capabilities for agricultural research in the developing countries of Asia. He has participated in reviews of agricultural research programmes and resources in India, Korea, Malaysia, Pakistan, the Philippines and Taiwan. He was consultant to the Working Group designated by the Government of Malaysia for the planning of the Malaysian Agricultural Research and Development Institute in 1968 and has served, on assignment from the Council, as the Director of MARDI during the first two years of its establishment.

ABOUT THE COUNCIL . . .

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National Agricultural Research Systems In Asia

Report of the Regional Seminar held at the India International Centre New Delhi, India March 8 - 13, 1971

Co-Sponsored by:

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Preface

The dramatic change in production of rice and wheat in Asia since 1966 demonstrates the potentials for renovation and growth of agriculture in this region. The boost in yields of these crops was the result of new combinations of inputs, carefully planned and systematically applied. Among these inputs, the 'packages of practices' of new technology resulting from problem-oriented, multi-disciplinary research — directed toward the various inhibitors to crop growth and productivity — were a basic factor.

The "Green Revolution" in Asia has created a greater awareness of the importance of adapted new technology, to assure sustained growth in agriculture and to protect those gains already achieved. Special attention has been directed toward the International Rice Research Institute, the source of the new technology for rice production, and to the international wheat improvement research programme which provided the 'Mexican Wheats'.

It is recognised that in addition to these specialised 'International Research Centers' the continuous infusion of new technology for agricultural growth and development to meet future needs of the region must depend increasingly upon 'national capabilities' in agricultural research. This is necessary because of the many production problems which are nation-specific or location-specific, tied to precise environments. This is particularly true in monsoon climates, even in small countries with varied topography and a wide range of soil types as in Malaysia.

The national research capabilities vary in the different countries of Asia. Some of the developing nations have taken action to strengthen these resources. Most have not.

The Agricultural Development Council, in recognition of the importance of improving agricultural research capabilities and systems on a national basis, took the initiative in September 1970 in planning the regional seminar on national agricultural research systems in Asia. Invitations were extended to individuals in charge of national research organisations, and to leaders of comprehensive national research projects in selected commodity or problem fields. The prompt and positive response, and the active participation in the conference of nearly all of the leaders of the major agricultural research institutions in this part of the world, reflect the wide-spread recognition of the importance of the task of strengthening national research resources.

India has given special attention to improvement of her national agricultural research and education structure for more than 15 years. In view of the progress achieved, and the availability of specific national projects to serve as working examples for study, the question of holding the Seminar in India was posed to the Indian Council of Agricultural Research. The ICAR not only agreed to the proposal that the seminar be held in India but also offered to serve as co-sponsor and host.

The Food and Agriculture Organisation of the UN, together with the United Nations Development Programme, also had been exploring during this time the possibility of a conference in Asia on agricultural research. The FAO/UNDP responded readily to the invitation to join in the sponsorship of the Seminar in New Delhi.

The sessions at the India International Centre during the week of March 8 through 13, 1971 were devoted in part to presentation of invited papers and also to discussions of selected problem areas. This report is organised on the basis of subject categories and does not follow the agenda of the Seminar.

Part I presents a review and assessment of present national research systems or capabilities. The historical base for development of the respective national research organisations is reviewed and some deficiencies, limitations, and restraints in improving the national research resource are identified.

Part II is concerned with organisation patterns and procedures in selected crop improvement research programmes in the several countries where such national projects have been set up or strengthened for research on rice, wheat and maize. These programmes furnish working examples of integrated, inter-disciplinary, problem-oriented research designed to increase crop productivity on a nation-wide basis.

Part III reviews international agricultural research resources, including some basic considerations in establishing the international research centres and the more specific activities of the International Rice Research Institute and the International Maize and Wheat Improvement Centre. This section of the seminar was designed not only to review the special international research resources but also their relationships with national research projects and systems.

Part IV considers national agronomic research programmes concerned with 'non-commodity' problems. The selected papers provide patterns of organisation of field research on improved use of land and water resources, on agronomic and cropping practices, and a resume of the multi-faceted research required to achieve greater intensification or diversification of agriculture — a matter of increasing concern in many developing nations.

Part V relates to some of the economic and social problems involved in — or arising from — agricultural modernisation and development. These subject areas often tend to lack a national focus or thrust and it is essential that greater attention be given to specific economic and social problems in national planning. Research on such problems may deal with less tangible factors than research with plants, crop pests and diseases, soils, water, etc. but this does not minimise the significance and relevance of national research efforts on economic and social adjustments related to agricultural development.

Part VI presents a digest of the discussion sessions on selected topics which were a significant and valuable part of the Seminar. No detailed report is presented

of these discussions but the general 'consensus of views' are summarised. In the paper on Highlights of the Seminar Dr. Mosher calls attention to a number of factors which should receive further study and consideration.

It was not possible to provide for presentation of all invited papers but it was understood that certain papers would be used as resource materials for discussion and would be included in the Seminar report. These resource papers are (1) The Tropical Agriculture Research Centre — Japan by Dr. Noburu Yamada, (2) Agricultural Research Organisation in Taiwan, and (3) Research to Guide Diversification by Dr. Hsiung Wan, and (4) The All-India Coordinated Agronomic Experiments Scheme by Dr. I. C. Mahapatra. Dr. Wan was not able to attend the Seminar but his papers are of special interest in view of the striking progress made in Taiwan during the past two decades in changing the productivity and diversification of her agriculture.

The principal objectives of the Seminar were, (1) to develop better understandings of the present national agricultural research organisations in Asia, (2) to identify strengths and shortcomings in the national capabilities, and (3) to consider the organisation and operation of some representative 'nation-wide' projects as components of national systems. It was not intended that any 'blueprint' or comprehensive plan for an ideal or preferred national research system should emerge from the Seminar since the needs and the opportunities for developing more effective national research systems differ in the various countries of Asia.

It is recognised that the substance and content of research is of primary importance, and the form of organisation is secondary. But individual scientists, no matter how competent, cannot be productive without a strong institutional base, with the dependable budgetary support and services essential for long range planning and conduct of research.

It is hoped that this opportunity for leaders of research in the region to consider jointly the subject of research organisation will furnish a base for future collaboration and interchange of views on the strengthening of national and regional resources for agricultural research in Asia.

ALBERT H. MOSEMAN.

November, 1971

Acknowledgements

A number of persons made special contributions to the success of the Seminar.

Dr. B. P. Pal, Director General of the Indian Council of Agricultural Research, served with the Editor of this Report as Co-Chairman of the Seminar and contributed in his usual effective manner throughout the sessions. Secretary K. P. A. Menon of the ICAR provided valuable assistance with the local arrangements. Mr. Balasubramaniam and his associates of the ICAR furnished most helpful secretarial services for the participants.

A word of thanks is given to Dr. M. S. Swaminathan and his colleagues of the Indian Agricultural Research Institute for the opportunity for Seminar participants to attend the special Symposium on March 11 on "The Green Revolution — The Next Phase". Dr. K. Kanungo, Dean of the Graduate School and Joint Director of the IARI, served as Chairman of one of the sessions of the Seminar and a number of other IARI staff members took an active part in the deliberations.

Dr. Shao-er Ong, Associate of the Agricultural Development Council located in Bangkok, arranged for the facilities at the India International Centre and assisted with the travel and related services for the participants supported by the ADC. Dr. Ong also provided for the processing and distribution of the invited papers prior to the seminar. Dr. A. M. Weisblat, Associate of the ADC in New Delhi, assisted with local arrangements.

Mr. V. W. Bruce of the Food and Agriculture Organisation of the UN arranged for co-sponsorship and support of the Seminar by the FAO/UNDP. Mr. Bruce and Mr. B. N. Webster of the FAO chaired sessions of the Seminar and participated actively in all of the discussions.

A note of special appreciation is extended to Mrs. Eu Kee Blencowe for assistance in the editing and preparation of the papers for this report. The help of the staff of the Malaysian Agricultural Research and Development Institute, particularly Mr. Lim Thye Yang, Miss Siti Rahmah bt. Hj. Harun and Miss Khadijah bt. Hamzah, in preparing the manuscript and in handling correspondence is also gratefully acknowledged.

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Introductory Address

B. P. PAL
Director General, The Indian Council of Agricultural Research,
New Delhi, India.

I consider it a very great privilege to be the Chairman of this opening session of a Seminar which I feel can have an important influence on the future development of agricultural research in developing countries. I would like to add my own very warm welcome to all those who are gathered here today on this occasion.

A detailed discussion on national agricultural research systems is most opportune. In recent years, as we are all aware, there has been a great increase in the human population and there have been dire prophecies about food shortages which might be expected in the near future, leading to the wiping out of whole populations. Also in many countries like India, which became independent only during the recent decades, where there is an upsurge for providing to the people of the country sufficient food to eat, and also the other things which a civilized nation requires, it has become imperative to place agriculture on a sound footing. Since this can only be done by adopting a modern agriculture based on science and technology, the research base which is all important has to be made sufficiently strong to meet the needs of the present and also of the future as far as we can predict requirements.

While the number of problems to be tackled and solved is vast — and with the greater demands and the increasing complexity of modern requirements the tasks ahead are tremendous — yet there is reason for hope and confidence because of recent, significant advances in food production. This recent experience, however, has underlined the importance of certain matters.

The first of these is the recognition that team work and a multi-disciplinary approach in applied agricultural research is absolutely necessary. Agricultural scientists are now fully aware of the need to try and wrest from the natural resources of soils and water supplies, the maximum that can be extracted per unit of time from a unit of land. There is also recognition of the important role that international cooperation can play in advancing agriculture. In the past, as we all know, there have been fruitful exchanges of plant materials between countries which are situated at great distances from each other. In this country, for instance, not only have certain crops originally come from other countries in the past but, more recently, male-sterile lines required for the production of high-yielding hybrids in sorghum and pearl millet have come from abroad. India, on her part, also has supplied to others many valuable plant materials including the famous sugarcane varieties bred at Coimbatore, some of which have had a great success in foreign countries.

In recent years we have seen the establishment of international research institutes such as the one on rice in the Philippines and the one dealing with wheat and maize in Mexico. These institutes, with their international staff of specialists, have played a dramatic role in recent years in increasing yields of some of the most important foodgrains crops.

In India, we have been fortunate to have a large network of research institutes and research centres. Some of these institutes were set up by the Government of India particularly to deal with long-range problems and those which transcended state boundaries. But the states in India also had established their own research institutes and agricultural colleges to deal with problems of agriculture. The Indian Council of Agricultural Research was set up in 1929 to provide a mechanism for coordinating the research effort of the country.

More recently, on the recommendation of expert teams, Agricultural Universities have been set up which have made possible the integration of research, teaching and extension in a way that was previously not possible. The first and primary purpose of the Agricultural Universities is to carry out research to solve the actual problems facing the farmers. In these institutions the teachers make use of the materials provided by the problem-oriented research. Extension education is also an important feature of these Universities. But the field of extension is of course a very big one, and there is room for fruitful cooperation between the research bodies and the State Departments of Agriculture in ensuring that both advice and inputs are duly made available to farmers.

The Indian Council of Agricultural Research, from the time it was set up, has been experimenting with patterns of simulating and sponsoring research. There was an early period when the Council considered only *ad hoc* research schemes and gave funds to those which were considered suitable by its Expert Committees. These schemes covered a wide range of subjects and I remember that there was even one for studying the kitchen swill from the Imperial Hotel! Then came a stage when the Council formulated a "model scheme" and left it to the various organisations to come forward with schemes on that model for financial support. But in recent years the Council has evolved a pattern of All-India Coordinated Research Projects which has proved to be exceedingly useful. This change first occurred at the time the Council was considering how to give a fillip to maize production in India, and particularly on how to utilize hybrid vigour which in America and elsewhere had made a tremendous impact on the production of this crop. The Council invited the Rockefeller Foundation to make available two experts who had worked in Mexico and South America under conditions more similar to India than those of Europe or the United States. Dr. U. J. Grant and Dr. E. J. Wellhausen were made available and they wrote a comprehensive report. In considering this report the Botany Committee of the Indian Council of Agricultural Research came to the conclusion that a new approach was required, based on the recognition of agro-climatic regions. Accordingly a project was drawn up in which the country was divided into agro-climatic zones and a research centre for work on maize was provided in each zone. For the first time, a Research Project Coordinator was made available and also a world collection of germplasm, the latter through the cooperation of the Rockefeller Foundation.

The research centres were located either in institutions belonging to the States, including Agricultural Universities, or in Central Institutes, depending upon their suitability for the work of the project. The programme was drawn up jointly by research scientists from all over the country and annual meetings were arranged

for the analysis of work and for drawing up of future programmes. This cooperative approach yielded quick dividends and the Council has now extended it not only to the improvement of other crop plants but also to research areas like those involving soils and water, the animal sciences, etc. It would, however, be of very great interest to us in this country to learn about the agricultural research systems which have been evolved in other countries and to see what we can learn from each other. We therefore, attach great importance to this conference where we can also discuss how we can cooperate more closely in research programmes.

Soon after independence it was decided by the Government of India that there should be a very thorough examination of the whole field of agricultural research and education and a number of expert teams were set up to do this from time to time. One of the very first of these was an Indo-American Team on Agricultural Research and Education and I am particularly happy that Dr. Moseman, who was an active member of that team, is here with us today. He also served on some other expert teams which were set up and we remember gratefully his personal contribution to the planning of a suitable research organisation for agriculture in India. We feel that evaluation of problems from time to time within a country is beneficial but, in addition to that, international collaboration is, in the modern context, absolutely essential.

I am exceedingly happy that participants have come from a large number of countries. These countries cover regions of the earth which differ greatly in soils and climate, and in plant and animal wealth. And the representatives of these countries come with rich experience of dealing with a variety of complex problems relating to the agricultural field. I feel very hopeful that the deliberations at this Seminar will lead to results of lasting value. The I.C.A.R. is deeply grateful to the Agricultural Development Council and the Food and Agriculture Organisation of the United Nations for collaborating with the Council in sponsoring what I hope will be a distinct landmark in the history of agricultural research organisation.

I thank you.

Inaugural Address

SHRI FAKHRUDDIN ALI AHMED

Minister of Food, Agriculture, Community Development & Cooperation, Government of India (presented by Dr. B. P. Pal, Director General, ICAR, in the absence of the Honourable Minister)

Mr. Chairman, Dr. Mosher, Dr. Chandler and friends,

I am very happy that the Indian Council of Agricultural Research has sponsored, in collaboration with the Food and Agriculture Organisation of the United Nations and the Agricultural Development Council, this International Seminar on the Development of National Agricultural Research Systems. I am indeed happy to welcome all the participants, particularly those who have come from other countries. We are grateful that so many of you could come here at a short notice. You have come at a time when you can see some of our winter crops like wheat which has registered a striking advance in productivity during the last few years. I am also happy that during your stay here you will be able to participate in another symposium on "The Green Revolution — the Next Phase" being organised by various scientific societies in the field of agriculture in our country. I believe that in order to develop and sustain a dynamic agricultural production programme, scientists must constantly review the various short term and long term effects of the new technology that they develop and suggest to the policy-maker the types of action plans that will be necessary to carry the green revolution forward — responsive to changes in demand, trade patterns, tastes and production needs of the multitude of farms.

In the last two years man has visited the moon a few times, an achievement which illustrates dramatically what modern science and technology can help to accomplish. Such remarkable success stories have also much guidance to offer on the kinds of decisions and action at the political, administrative, scientific and extension levels necessary for achieving the desired growth rate in agriculture. This question is of course a bigger one than what you propose to discuss at this seminar but is nevertheless relevant to increasing the capability and effectiveness of a National Agricultural Research System. Being a politician, I am concerned only with the end-result. I can only say that the national agricultural research system should be so developed as to make agriculture not only an instrument of self-sufficiency in food but also of rapid economic growth. It is up to you then to give thought to the mechanisms by which this end-result can be accomplished. You will have to break it down into all the components of organization including the financial and management implications of giving effect to a political decision.

We have often heard in the past that agricultural research in the developing nations is "ivory tower" research. This is because of the fact that the work of

the research had very little impact on either the practices adopted by the farmers or on productivity. In retrospect, it is clear that if research had little impact on the actual farming conditions, the fault cannot be attributed solely to the scientist. There is afterall no big difference between "ivory tower" research and research of very great applied value, if no steps are taken to produce and make available the inputs that are necessary for the farmer to take advantage of the scientific findings. It is for this reason that when we decided some years ago that India should be launched on the path of scientific agriculture, we proceeded with the creation of the necessary infra-structure. Thus, the National Seeds Corporation was established to produce the foundation seeds of hybrids and of high-yielding varieties; the Price Commission was constituted to recommend a price which is remunerative to the farmer and reasonable to the consumer, and a Food Corporation was established to purchase the grains produced by the farmers at the prices fixed by the Government of India on the recommendation of the Price Commission. Even after the establishment of all these agencies, we found that the availability of cheap and timely credit was one of the greatest impediments in the way of adoption of the new agricultural technology by our farmers. Then we decided to nationalise the leading banks and channel the available credit to the millions of small farmers in the country. I am mentioning all this in order to stress the fact that to develop a successful national agricultural research system, it is essential to produce the developmental milieu in which the results of research can find immediate application.

Today, the agricultural scientist in our country occupies the pride of place among all scientists. The importance given to agricultural science by our society has in turn acted as a stimulant in making the agricultural scientist give his best to the society. Unless the scientist has a feeling that his work is important, his brain will not be aroused. One can see this clearly in the explosion of scientific knowledge which has taken place in Europe and North America and in Japan during the World Wars.

Ours is a country with a Federal Constitution. Agriculture under our constitution is predominantly a State subject. Therefore, the responsibility of the Central Government to agricultural development is an indirect one. Unless each State has a strong research institution, many of the local problems cannot be easily solved. This is why in our overall strategy for agricultural development in the country, we have promoted the establishment of at least one agricultural university in each State. I am glad you will be visiting the first of such universities which was set up ten years ago at Pantnagar in Uttar Pradesh and you can see for yourself the philosophy and purpose behind the establishment of such institutions. While we are concentrating on helping State Governments to establish strong research and training centres, we are aware of the need for a national research system which can help to co-ordinate research in various fields and which can assume a series of service functions. For example, pests and pathogens do not recognise state boundaries and therefore it is essential to have a national approach in the study and control of pests and pathogens.

In the development of a national research system we have acted on the following principles:

First, we believe that only a strong interacting cluster of scientists belonging to different disciplines will be able to deliver results quickly. In other words, there must be a few strong national centres which are well-staffed and well-equipped, which can help both in undertaking research of a path-breaking

nature and also provide high level training. You will be visiting our premier national research centre for agriculture when you go to the Indian Agricultural Research Institute at New Delhi.

Secondly, there should be a link up between research institutions working on the same problems under different administrative authorities. Similarly, there must be a link up between scientists working on various field-oriented problems. It is to provide these two kinds of link up that we devised the All-India Co-ordinated Projects approach. You will be hearing from Dr. Pal more about this approach and also from different Project Co-ordinators as to how this operates in practice.

Finally, we believe that there must be very strong educational programmes at various levels in order to ensure that the country's research system is supplied with high quality manpower imbibed with the right philosophy to work. Against this background we established the Post-graduate School at the Indian Agricultural Research which has provided the country with over 1500 Ph.D. and M.Scs. during the last 12 years.

Through the National Demonstration Programme and through various extension departments attached to our research institutions and agricultural universities, we have attempted to develop feedback relationships among scientists, extension workers and farmers. Perhaps as you go into this more fully, you will come to the conclusion, as I have, that the relationship so established is not yet very close, integrated or complete. Our system of adaptive research has to be further strengthened and vastly enlarged. May be your discussions will give us the framework for its organisation.

I have so far spoken only about our national research system but we realise only too well the benefits that have accrued and will accrue in future by forging strong links with international research organizations. FAO has always been very helpful and the new international research institutes like the International Wheat and Maize Improvement Centre in Mexico and the International Rice Research Institute in the Philippines have played an important role in spreading the tools and message of high yields. We, therefore, feel that all national research systems should develop working bonds with such international research organisations and centres. We have also been advocating a closer liaison between various scientific institutions located in different regions in the world. There are many experiences which we can share with other developing and developed nations for we have affinities of climate, similarities of developmental problems, the same pains of growth and constraints of resources. We could do well to draw on each other's research experience and avoid duplication.

I am happy that Dr. Chandler, Director of the International Rice Research Institute is with us. It would indeed be an honour that Dr. N. E. Borlaug who was awarded the Nobel Peace Prize for 1970 will be addressing you tomorrow. I would also like to welcome and express our gratitude to Dr. A. T. Mosher, President of the Agricultural Development Council who has taken so much interest in the growth of our agriculture. We consider him as one of us since he lived and worked with us for many years as the Principal of the Agricultural College at Allahabad and his interest in our welfare is abiding. I wish your deliberations all success.

Building Agricultural Research Capabilities

ALBERT H. MOSEMAN

Associate, Agricultural Development Council, and Director, Malaysian Agricultural Research and Development Institute, Kuala Lumpur, Malaysia.

It is most appropriate that the Indian Council of Agricultural Research should serve as host to this seminar, in view of the positive actions taken by this organisation and by the Government of India to re-shape and strengthen national research capabilities. The All-India schemes for increasing food grain production in recent years provide patterns for possible application by other countries where agricultural development has high priority.

Today, March 8, has special personal significance. It was 21 years ago, on March 8, 1950, that I first visited India. At that time Dr. Pal was Acting Director of the Indian Agricultural Research Institute and the wheat breeder at IARI. Indian wheats, then shoulder-high to Dr. Pal, have since changed in stature and in productivity. The same can be said for the ICAR and for Dr. Pal, its Director General.

1950 CONCEPTS — EXTENSION AND SHARING OF NEW TECHNOLOGY

In the review of agricultural problems and potentials for technical collaboration in India in 1950, by the special team of the U.S. State Department of which I was a member, we were interested in identifying prospects for sharing advances in U.S. science and technology with developing countries. This was the thrust of 'Point IV' in the inaugural message of President Truman in January, 1949.

Special attention was given to procedures for expediting application not only of potentially usable U.S. agricultural technology but also the research from local institutions. This basic concern about improved 'extension services' prevailed in the reviews by the U.S. Agricultural Team in visits to Egypt, Lebanon, Syria, Iraq, Iran, Pakistan, India, Thailand and the Philippines.

The high priority given to the sharing and application of available technology, in the discussions with government officials across the Near and Middle East countries and in Asia, contributed to the strong emphasis on programmes in extension and community development in the U.S. technical assistance programmes of the 1950's.

While it was recognised that developing countries should also give attention to the strengthening of their indigenous agricultural research capabilities, this was not emphasised and was largely ignored in the early years of implementation of the cooperative U.S. Point IV activities. There were, of course, some 'research projects' such as the soil fertility studies in India at the early stages of the technical cooperation programme. Support was given also to strengthening and developing agricultural universities, but primarily on the teaching or education side.

ADAPTIVE RESEARCH

There were some successes in the transfer of materials and practices from agriculturally advanced countries during the decade of the 1950's. But there were also many disappointments. Materials and technology developed for temperate zone agriculture are usually not suited to tropical environments, especially to monsoon climates.

During the first decade of U.S. technical cooperation in Asia there was a lack of distinction on the part of many U.S. technical assistance leaders between (a) direct extension or transfer of new technology and (b) adaptive research approaches to modify and fit potential innovations to specific conditions. This was still apparent in 1965 when efforts were made to strengthen research and technology inputs of the U.S. Agency for International Development. The reaction of some leading USAID officials at that time was, 'we have had *agricultural technicians* in our cooperative programmes for more than ten years with no appreciable results'.

As recently as 1966, in the first year of Asia's 'Green Revolution', it was most difficult to obtain acceptance within USAID for support to the International Rice Research Institute for cooperative adaptive research to improve rice production in India, Pakistan, and other countries where shortages of this food grain were then reaching critical proportions.

The U.S. experience in transfer and application of agricultural technology through problem-oriented, adaptive research, conducted by scientists working in the host countries, dates back to the early 1940's and the programme of the U.S. Department of Agriculture Office of Foreign Agriculture Relations. The agricultural programme of the Rockefeller Foundation initiated in 1943 in Mexico, with its strong emphasis on improved production of food crops, followed this pattern. The wheat improvement project initiated at that time with the Government of Mexico was extended through cooperative research programmes into Columbia, Chile, Ecuador, Peru and other countries in Latin America during the 1950's.

THE BASE FOR THE GREEN REVOLUTION ERA, 1966–1970

With the support of the Rockefeller Foundation, and the cooperation of the Food and Agriculture Organisation of the U.N., the wheat improvement research was extended during the early 1960's through cooperative variety trials in the Near and Middle East countries. Special training programmes were also conducted in Mexico for plant breeders from these countries. The wheat improvement research was extended further into Asia through cooperative programmes supported by the Ford Foundation and the Rockefeller Foundation in Pakistan and India beginning in 1964-1965.

These cooperative 'research-based' activities furnished the 'location-specific' evidence and assurance that the new wheat varieties and production practices first

K. P. A. Menon, Secretary of the Indian Council of Agricultural Research, welcomes participants to the Seminar. Seated, left to right, Victor W. Bruce, The Food and Agriculture Organisation of the UN; Albert H. Moseman, The Agricultural Development Council, and B. P. Pal, Director General, Indian Council of Agricultural Research (Co-Chairmen of the Seminar); and J. C. Mathur, Additional Secretary, Union Ministry for Food, Agriculture, Community Development and Cooperation.

Participants in the Seminar on National Agricultural Research Systems in Asia, held at the India International Centre, New Delhi. March 8 — 13, 1971.

developed in Mexico were well adapted to the different soils and climates in the wheat growing regions of these countries by the time the intensive production programmes were activated in 1965-66.

The establishment of the International Rice Research Institute in the Philippines in 1962 came about after several years of effort by the Rockefeller Foundation to strengthen research capabilities in the rice bowl countries of Asia through grants and training awards to selected institutions. The decision in 1959, jointly by the Rockefeller Foundation and the Ford Foundation, to establish a special institute for problem-oriented, multi-disciplinary research on all aspects of rice production reflected the lack of recognition on the part of government leaders in most countries of Asia at that time of the importance of a strong input of new technology for agricultural development.

The new rice production technology, based on the high yielding varieties from the International Rice Research Institute, represents a truly remarkable short term achievement. Within five years after the decision to establish the IRRI not only were the higher yielding varieties and improved production practices available, but cooperative linkages had been established with most countries in Asia to evaluate and exploit promptly the results of the Institute's research. An effective cooperative training programme had been established to provide working experience for young scientists in the laboratories and field plots at IRRI to ensure maximum understanding of the importance of combining advances in the several scientific disciplines into 'new packages of practices'.

While the new rice production technology had been under test for a shorter period than the wheat varieties at the time of its intensive application, there was considerable evidence accumulated throughout the region by 1966 of the exceptional yielding potential of the IRRI varieties under a wide range of growing conditions.

THE AFTERMATH OF THE GREEN REVOLUTION

The drastically changed pattern of wheat and rice production in Asia during the past five years has caused a reassessment of the forces in agricultural growth and development. An increasing number of countries look forward to 'self-sufficiency' — meeting their national needs for rice production. The Philippines and Pakistan essentially achieved this goal in 1968-1969. India, Malaysia, Ceylon and Indonesia anticipate reaching their national requirements within the next few years. International and domestic markets will face substantial adjustments in meeting these new patterns of production.

Much has been said and written about 'second generation problems' including inadequacies of transportation, storage and marketing facilities. Most of these problems are not new — and perhaps they should have been anticipated to a greater degree. The special review in India in 1959 by the Agricultural Production Team supported by the Ford Foundation called attention to the need for more than one hundred million tons of food grain by 1965 if the anticipated population of India by that time was to be fed. The scale of the infrastructure necessary for the handling of this magnitude of food grains — whether produced largely domestically or imported from abroad — was, therefore, identified long before the Green Revolution years of 1966-1970.

There is growing concern about the social impact of new patterns of productivity, particularly the possible further disparity of income between those who

have suitable land and water resources and levels of income to afford new production inputs — as contrasted with those farmers who lack these resources. There will be an accelerated migration from rural areas as new technology enables fewer acres, and fewer agricultural workers, to produce larger quantities of food supplies and other agricultural products. There may be greater unemployment in both rural and urban areas.

It is not meaningful, or desirable, to categorise certain factors as 'first generation' and others as 'second generation'. Agricultural development involves a sustained increase in productivity with many elements requiring continuing and simultaneous consideration.

The strong current emphasis on the storage, marketing and transportation infrastructure problems — and on the economic and social factors — tends to suggest that these have over-riding importance for immediate attention while the biological and agronomic inputs are well in hand for needs of the future. Perpetuation of this concept would be most unfortunate and we could well anticipate that an *excessive shift* of attention to those factors in the forefront of today's concern could well bring deficiencies in biological inputs into priority as the 'third generation problems' a decade from now.

We have recognised that balanced combinations of technological inputs as 'packages of practices' are important in boosting crop productivity. We do not look upon the distinct technologies relating to genetic improvement, soil fertility, water management, and disease and pest control as having any real first or second generation priorities. It is well, similarly, to guard against excessive fragmentation or phasing of the broader interacting technical, economic and social factors involved in agricultural development.

The foregoing statement may seem to be in contradiction to the specific focus of this seminar on research. This is not so since we are mindful of the need for research on the many inter-related factors in development, including new technology, provision of production inputs, incentives, facilities for storage and distribution, resource planning — land and water as well as human — and other elements in the improvement of agriculture. All of these would be embraced within an effective national organisation or system for agricultural research.

THE PURPOSE AND FOCUS OF THE SEMINAR

The accelerated food production programmes in countries of Asia during the past five years were set up largely on a special-project, emergency basis. They were in most cases established outside of the regular research and extension framework of government. As such special projects they had the advantage of autonomous, expeditious action necessary to meet the immediate task at hand. The magnitude of the food production problem caused the attention of top government leaders to be directed to these intensive projects.

As the food crisis has diminished there has been some carryover of recognition of the importance of research and technology in agricultural development. And there is a continuing interest on the part of many public and private, national and international, technical and economic assistance organisations in improving research capabilities. This interest is shared to varying degrees by leaders in a number of the developing countries.

While there is a greater appreciation today than there was five years ago of the need for institutionalised agricultural research to meet growing world-wide requirements there is no real consensus of judgment on the structure of such research capabilities. Some are urging priority attention to establishment of more highly integrated *international* research centres, patterned after the International Rice Research Institute. Others would place greater emphasis on the strengthening of *national* research resources.

There is room — and a distinct need — for research resources at both the international and national level. Such resources can be mutually supportive, if properly considered, or they can be unduly competitive for staff and funding, if there is a lack of attention to their potential interrelationships.

The patterns for the *international* centres are rather well established, with the recent experience in the setting up of the International Rice Research Institute (IRRI) in the Philippines, the International Maize and Wheat Improvement Centre (CIMMYT) in Mexico, and the centres for International Tropical Agriculture in Colombia and Nigeria.

The types of research organisations or systems best suited to meet *national* requirements are less well defined. And especially important is a better understanding of the procedures and the forces involved in the development of improved national research capabilities.

There is little expertise and there are few models for guiding the building of national research systems. We tend to promote our individual experiences. I am partial to the U.S. system involving the Agricultural Research Service of the U.S. Department of Agriculture and the cooperating experiment stations of the Land Grant Universities. This bias stems not only from personal experience with that U.S. system but also with the agricultural programmes of the Rockefeller Foundation in which the wheat and maize improvement research has followed a similar pattern. In the latter case the *countries* of Latin America and of Asia furnish the type of expanded collaboration which is supplied by the *stvtes* in the U.S. system.

In the strengthening of national research capabilities in Asia we need not depend only on experience from the more highly organised research structures of countries with advanced agricultural sectors. The efforts in many countries of Asia in improving research and educational institutions over the past two decades, together with the more recent participation of the IRRI, furnish an effective base for study and evaluation. The interchange of ideas and experiences at this time should help to broaden understandings of the roles and relationships of international and national organisations. And the opportunity mutually to identify some of the inhibitors will be useful in meeting such obstacles in the future.

The programme of this seminar is designed to give attention to:

(1) The present status of national agricultural organisations or systems in selected countries of Asia, particularly those in which special efforts have been made to strengthen research capabilities in recent years.

(2) The functions and potential roles of international research institutes or centres.

(3) The review of national research projects or schemes set up to increase food grain production, the relationship of such projects to the international research institutes and their usefulness in building national organisations.

(4) The consideration of selected economic and social problems which must receive much more research attention.

INTERNATIONAL RESEARCH INSTITUTES OR CENTRES

There are several papers in the seminar concerned with the features and role of the international research centres, including the International Rice Research Institute (IRRI) and the International Maize and Wheat Improvement Centre (CIMMYT).

There has been extensive experience with such highly integrated, multi-disciplinary research centres, including the institutes established for research on oil palm, cocoa and rubber by the British in Africa; the Central Research Institutes in India; the Pineapple Research Institute and the Sugar Planters Experiment Station in Hawaii; and the Rubber Research Institute of Malaya. The Inter-American Institute for Agricultural Sciences at Turrialba, Costa Rica and the special Bankhead-Jones laboratories established for selected commodity or regional research in the United States just prior to World War II are other examples.

There are distinct advantages in developing new technology through concentration of attention by teams of scientists, so located as to facilitate exchange of ideas and to plan and carry out multi-factor studies. The exceptional progress in rice improvement by the IRRI furnishes ample evidence of the effectiveness of this organisational pattern.

The outstanding contribution of the IRRI during the past five years could, however, have potentially deleterious effect on the development of the scope of research capabilities necessary to meet the needs of Asia in the years ahead. Some organisations not previously committed to support of research in agricultural development have tended to 'opt for the obvious' and presume that new technology inputs of the future can be supplied largely from a few international research centres. This viewpoint could serve to channel an excessive portion of resources from donor technical and economic assistance organisations toward such centres and further defer and reduce support for strengthening of national capabilities for research on the many problems which are location-specific or country-specific.

It must be kept in mind that there are distinct limitations as well as advantages in concentration of research resources into a few large centres. Many of the specialised institutes referred to above have made only limited impact over extended geographic regions. None has had the timely and rapid impact of IRRI over so much of the world.

The potential for other types of allocation of research resources for international programmes is demonstrated by the evolution of the 'Mexican wheats' and related production technology developed by Dr. Norman E. Borlaug and his colleagues in the cooperative programmes of the Rockefeller Foundation and the Government of Mexico. It is rather widely assumed that these wheats were produced by the International Maize and Wheat Improvement Centre, CIMMYT. They were, however, developed prior to the establishment of CIMMYT, from a more

dispersed cooperative research programme in which many countries were involved. The new wheats were already making their impact in Asia at the time CIMMYT was inaugurated. Thus, the improved wheat varieties and production practices are not the product of CIMMYT, but rather CIMMYT is the outgrowth — and subsequent institutionalisation — of cooperative efforts extending over a number of years with many countries. The time span for such cooperative accomplishments could be shortened considerably if the participating countries had more effective research capabilities to offer in this type of partnership.

The foregoing comments should not be construed as minimising the importance of the integrated international research centre as an effective contributor to agricultural development. In fact, such centres will have a continuing major role so long as national research capabilities are deficient and are not receiving adequate support from the respective government leaders. The new technology from the international centres may well be the major growth inputs in many countries for some time in the future. And the training programmes will have continuing importance in building scientific staff competence in the region.

The international centres will also exert an important influence in building *organisational* strength in the cooperating countries. The intensive wheat and rice production schemes of recent years, which were set up on essentially an emergency adaptive research and testing basis, furnish not only a potential continuing crop improvement resource but also serve as a pattern for other research of national or regional scope within a country.

NATIONAL RESEARCH ORGANISATIONS AND SYSTEMS

While international research centres and national research systems may tend to be competitive for supporting funds and resources at the present time, they should be complementary and interdependent. The continuing flow and interchange of science and technology requires basic capabilities and strength from both the 'international' and 'national' cooperators.

The experience *within* highly organised national agricultural research systems is relevant in assessing significance of centralised and dispersed cooperating organisations. In the United States the effectiveness of federal agricultural research inputs depends largely upon the capability of the cooperating state agricultural experiment stations. I believe it is fair to say also that a limiting factor in the past in the role of the specialised commodity research institutes in India—in their impact on the agriculture of this country — was the limited research capability at the state level. This is now being remedied in part by the emerging agricultural universities and by the All-India Coordinated Schemes which involve both Central and State resources.

The Rockefeller Foundation programme in Agricultural Sciences was most effective in its expansion into those cooperating countries where there was research competence at the national level. In many cases this was supplied by location of trained scientists from the Foundation in the cooperating country.

A handicap in establishing effective cooperation in Malaysia with the Regional Maize and Sorghum Research Centre in Thailand has been the lack of continuity of Maize research workers in Malaysia. At the seven regional Maize Improvement Workshops sponsored by the Centre since 1964, Malaysia has been represented by eleven different research workers. The two representatives in 1970/71 were new to the workshop — had not attended previous ones.

This type of situation reflects the limited research capability and staff resource in many countries where competing demands cause research workers to be shifted abruptly from one research task to another, or frequently to non-research assignments. We expect the establishment of the Malaysian Agricultural Research and Development Institute, MARDI, as an autonomous body, to insure greater continuity and the development of research specialisation and competence in the future.

NATION — SPECIFIC RESEARCH PROJECTS

There are many problems which must be served by national research organisations.

It is necessary to modify crop varieties as well as cultural practices and disease and pest control measures to fit different soils and moisture regimes which may vary widely even within relatively small countries, particularly under monsoon rainfall conditions. Similarly, animal production must be geared to widely variable climatic factors and to areas which differ in feed production potentials. Adaptive research is necessary also to modify product quality, to meet consumer preference in both domestic and world markets.

The importance of *protective* research comes to the forefront constantly. The heavy losses to the maize crop in the United States in 1970, because of the epidemic spread of the *Helminthosporium* blight, emphasises the fact that even with well organised systems of agricultural research it is difficult to keep crop pests and diseases in hand. The range of virus, fungus, and bacterial diseases affecting crop plants is great and the appearance of new virulent races or strains is unpredictable. There must be the capability within each country to identify promptly and to counteract new diseases or new forms of existing diseases and pests.

Rubber production in Malaysia has maintained its position as the backbone of the agricultural economy through effective research, not only to improve production and efficiency of production, but also to improve the quality and market appeal of Malaysian natural rubber. The successful diversification or adjustments in agriculture in Malaysia will depend on the development of suitable profitable alternatives.

The rapid increase in the production of corn and other crops in Thailand, to diversify an agriculture once based almost entirely on rice, has been fostered through research and testing of varieties and production practices under the growing conditions of that country.

National capabilities in agricultural research are especially important in guiding land development or rural development activities. Economic and social factors as well as biological factors must be assessed in determining the kinds of agricultural enterprises to be emphasised in new land development schemes. These factors are not only nation-specific but also location-specific.

The importance of suitable background information is clearly evident in Malaysia as studies are undertaken to plan substantial new land development schemes in the states of Johore and Pahang during the next five years. The kinds of answers needed to guide these development projects must relate to precise local conditions and cannot be furnished from external sources.

ECONOMIC AND SOCIAL PROBLEMS

It is relatively simple to plan and carry out research in many of the biological science fields — such as those relating to crop improvement. Those concerned with physical and biological engineering have the tools to tackle specific problems and objectives.

We lack similar recipes for research on many of the economic and social factors in development since the intangibles as well as the identifiable elements are so highly variable. Studies in land tenure, on combinations of production enterprises, marketing systems, and agricultural adjustments must take into account highly localised conditions. General — external — research has limited relevance.

We have a few papers — admittedly too few — in this seminar on some of the economic and social problems which should receive greater attention in national research systems. The sharpening of our research tools in this sector is most important, to help *forestall* as many as possible of the problems of economic and human dislocation attendant to change and modernisation of agriculture.

SOME GENERAL CONSIDERATIONS

The improvement of national research capabilities is especially significant today as newly emerging nations are increasing their efforts to achieve greater self-reliance. Nearly a quarter of a century, or one generation, has passed since India and Pakistan gained their independence in 1947. Malaysia, Indonesia, and other countries in Asia have had a shorter time span to establish their national identities and capabilities.

New nations cannot achieve true political independence unless they also have the intellectual independence supplied by their own national institutions. It is important for technical and economic assistance organisations to recognise that perpetuation of the concept that developing nations must continue to be dependent on outside sources for their science and technology is not in keeping with today's commitments to build greater equality among peoples of the world.

We should reject the notion that developing nations cannot afford the expenditures for national research capabilities. There are in fact few investments better designed to ensure sustained growth and stability than the strengthening of national education and research institutions.

The United States, in the 1860's had limited national wealth and low per capita income. However, our national leaders at that time elected not to remain dependent on European institutions to serve our national development needs. More than a half century elapsed in the establishment of the nation-wide system of research and extension services in the United States. This time for building effective institutions can be reduced substantially by applying the combined experience from other countries and — most importantly — from the past two decades of experience in the countries of Asia.

There is no formula for instant institutional development. There is no omniscience and little experience in this field. Models may be helpful. Working experience is more useful. While the development of research systems cannot be done by experts, neither can it be left entirely to chance. And it is essential that the complex task of strengthening national research capabilities be given priority attention if a steady pace of agricultural and economic development is to be achieved in the decades ahead.

Part I

National Research Systems

Agricultural Research Organisation And Operations In Ceylon

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The responsibility for agricultural research in Ceylon rests with a number of different organisations. The Department of Agriculture, the most important of these, has the responsibility of conducting research on rice, subsidiary food crops, cotton, minor plantation crops, vegetables, fruit, pastures and livestock. The major plantation crops are looked after by the tea, rubber and coconut research institutes which are autonomous bodies. Land usage research is entrusted to the Department of Irrigation while the Sugar Corporation of Ceylon looks after sugar. In addition, the Faculty of Agriculture of the University of Ceylon, Peradeniya, also conducts research into various aspects of agriculture.

RESEARCH ORGANISATION

Major attention in this paper is given to research into food crops which is undertaken by the Department of Agriculture, the single most important organisation dealing with research in agriculture. Agricultural research in the Department of Agriculture is organised into two separate divisions: crop husbandry including pasture research is dealt with by the Division of Agricultural Research while animal husbandry and veterinary research is done by the Division of Animal Health and Production.

The Division of Agricultural Research is under the charge of a Deputy Director of Agriculture (Research) and is organised in the form of a Central Agricultural Research Institute, located at Peradeniya, and a number of research stations and sub-stations located in different parts of the Island.

Research, in the main, has been organised around individual crops and disciplines. Thus the Central Agricultural Research Institute comprises the Divisions of Agricultural Botany, Agricultural Chemistry, Plant Pathology, Entomology, Horticulture, Food Technology, Minor Plantation Crops, Tobacco, Soil Conservation and Statistics. The regional research stations have been established in different agro-climatic regions to deal with problems specific to those areas. There exist at present a Dry-Zone Research Station, two hill country research stations for dry and wet climates respectively, a Central Rice Breeding Station and a Cotton Research Station. These stations do not fully cover the major agro-climatic regions in the country and the development plans envisage the setting up of at least eight regional

research stations. The organisation of the regional stations at present reflects the organisation of the Central Research Station.

RESEARCH STAFF

The Research Division of the Department of Agriculture employs three categories of staff. There are the research officers who are generally recruited from candidates holding a first or second class degree in science or agriculture. These officers generally undergo a course of post-graduate training overseas. The second category of experimental officers is a relatively recent introduction. Such officers are generally confined to pass degree holders in science or agriculture. The third category of officers, referred to as agricultural instructors, are recruited from those who possess a diploma from the Schools of Agriculture.

The research staff at present is estimated at 64 research officers, 36 experimental officers and 57 agricultural instructors. Of the research officers, approximately 20 have had post-graduate overseas training and another ten are presently undergoing such training. It is estimated that 80% of the research staff is located at the Central Agricultural Research Institute and the Dry-Zone Research Institute. 60% of them are engaged in rice research. While it is evident that there is a sparse scatter of research staff amongst the other research stations, crops and disciplines, the position with regard to irrigation and water management, farm machinery and processing, and agricultural economics and farm management is very unsatisfactory.

RESEARCH OPERATIONS

It is evident that agricultural research in the Department of Agriculture is concentrated heavily on rice. This is because rice occupies 35% of the total cropped area, with coconut, tea, and rubber occupying 25, 14, and 14% respectively; all other crops together accounting for only 12% of the total cropped area.

The most outstanding contribution to rice research lies in the development of the H4 and H8 varieties with yield potentials of 160 bushels to the acre. At present, the major objective of rice research is the development of new high-yielding varieties which are 'insensitive to the photoperiod and resistant to disease'. Attention is also directed toward the breeding of varieties tolerant of badly drained soil conditions and the low light intensities which characterise monsoon periods. Considerable importance is also attached to the development of short-age rice varieties including upland rice in view of the large extents of land which still depend on natural rainfall. In addition, efforts are also underway to survey and classify rice soils, determine the manuring and fertiliser requirements of rice soils and improve fertiliser and manuring practices. There is also a continuing search for reliable sources of resistance to the major pests and diseases of the rice plant and to improve the efficiency of the chemical control of pests and diseases.

With the current emphasis on import substitution, increasing attention is also being given to subsidiary food crops, mainly chillies and onions. Here too, research is focussed on the development of new high-yielding varieties which are disease resistant. Much of this work is being carried on at the Dry-Zone Research Station. In the past, the major objective at this station was development of new systems of farming to replace the shifting cultivation which still remains the chief means of exploiting the non-irrigable land in the dry zone, amounting to over 3.5 million acres. But with the proposed Mahaweli Ganga Diversion Scheme expected to provide an assured water supply to about 900,000 acres, emphasis is shifting to

problems of irrigated farming with special attention to the optimum use of water. A start is also being made to develop suitable programmes of multiple cropping and crop diversification. The significance of research on multiple cropping and crop diversification in the years to come is well realised, but there seems to be an inadequate deployment of personnel, due mainly to the lack of trained people.

The two hill country research stations are concerned with investigations on pastures which they share with the Dry-Zone Research Institute, and potato, vegetable and fruit cultivation. A large number of trials are being conducted with introduced varieties of grasses and legumes, fruit and vegetables.

NEW DIRECTIONS IN RESEARCH

While there has been considerable progress in the sphere of agricultural research in the past, the shortcomings of the existing organisation are also well realised. A major handicap has been the tendency to work in isolation in terms of disciplines and crops. With the greater emphasis on problem solving, there is a great need for regional specialisation in terms of agro-climatic zones and an interdisciplinary approach which can only be realised if research work is undertaken by research teams rather than by individuals. It is also realised that whereas in the past there was a concentration of effort on rice research, the future will require a shift of focus towards the development of new systems of farming, new crops and enterprise combinations. The hold up is likely to be in the availability of trained people.

A major research vacuum exists in the area of agricultural economics and agricultural engineering including water management. There exist at present only two units capable of undertaking research in agricultural economics, and each unit has only one officer trained in agricultural economics. These units came into existence only during the last couple of years. The proposed Agrarian Research Institute to be set up with F.A.O./U.N.D.P. assistance should fill the research gap. The U.N.D.P. Crop Diversification Project, presently confined to smallholdings in the export sector should also prove valuable. In the field of agricultural engineering, a machine and designs testing unit was set up recently. But research in water management and crop processing still continue to lag behind.

There is also a pressing need for an evaluation of the physical resources of the country. At present, in respect of agriculture, a number of different organisations such as the Land Use Division of the Department of Irrigation, the Water Resources Board and the Agricultural Chemistry Division of the Department of Agriculture are engaged in compiling the basic data on physical resources. However, they operate independently and lack any co-ordination. The same problem obtains for research into other aspects of agriculture. In view of the shortage of trained personnel and the rather meagre resources devoted to agricultural research, a unified research programme which could coordinate the activities of the Department of Agriculture, Irrigation and Lands, the three research institutes servicing the export crops, the Sugar Corporation and the University Department of Agriculture, is an urgent need. The Ministry of Scientific Research was set up a few years ago with such a development in view; to date, no positive steps have been taken in this direction.

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Building Agricultural Research Organisations —The Indian Experience

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It is now well recognised and appreciated that agricultural research is the foundation for increased agricultural production. The 'Green Revolution' in India is the result of the systematic application of improved agricultural technology for crop production. Since improved agricultural technology stems from problem-oriented research, maximum attention has to be given to the organisations conducting research. This has been recognised and accepted in India during the last two decades. Not only are we laying more and more emphasis on agricultural research but the organisations conducting research have also come in for critical review by teams of experts at frequent intervals.

After India attained independence in 1947, a new awareness of the problems connected with her economic development (comparable to Japan after the Meiji Restoration of 1868) was felt in the country. Agriculture is the most important industry in the country, and planners have had to keep the attainment of self-sufficiency in agricultural production as one of the main objectives.

AGRICULTURAL RESEARCH IN INDIA BEFORE INDEPENDENCE

The British Empire in India was built on the base of the administration taken over by the British Parliament from the East India Company. Some of the research and educational institutions in the country today date back to the 1800's or the early 1900's. The well-known Agricultural College and Research Institute, Coimbatore, started as a model farm established at Saidapet, near Madras, in 1868 and was later converted into an agricultural school. The Bacteriological Research Laboratory in veterinary science was established in 1889 at Poona; it was moved to Mukteswar and ultimately became the Indian Veterinary Research Institute with its main campus at Izatnagar (Bareilly). The Indian Agricultural Research Institute, which is the largest research institute complex in the country and one of the finest centres of post-graduate education, was started at Pusa in 1905.

India was one of Britain's most important colonies for production of raw materials and a major market for her finished goods. This was reflected in colonial Britain's approach to the problems connected with agricultural research and development. The Indian Central Cotton Committee which was responsible for

increasing production of cotton for the mills in England was established even before the registration of the Indian Council of Agricultural Research in 1929.

Constitutional changes in 1919 made agriculture a provincial subject. Since some important research institutes had been established by the Central Government before the provinces were given primary responsibility for agriculture, including research, it was felt that some agency was needed to coordinate the research activities of the Centre and the provinces. The Royal Commission on Agriculture, set up in 1928, studied this problem in depth and recommended the establishment of a Central Council of Agricultural Research. The Imperial Council of Agricultural Research (subsequently the Indian Council of Agricultural Research) was established in 1929.

Though entrusted with wide responsibilities, the Council never had the opportunity to play a prominent role in coordinating and promoting agricultural research throughout the country. On the model of the Indian Central Cotton Committee, many other commodity committees were set up to assume autonomous responsibilities. The Council never established its own laboratories or research institutes. A number of 'Central Institutes' were established under the Ministry of Food and Agriculture. A number of agricultural colleges were also set up, the oldest and most important being the ones at Coimbatore, Poona, Nagpur, Kanpur and Lyallpur (now in Pakistan). The Indian Agricultural Research Institute, for many years, had a strong centre of post-graduate education. Though the Post-Graduate School was established at the Indian Agricultural Research Institute and the Institute was given the status of a university only in 1958, following the recommendations of the First Indo-American Team, the previous 'Associateship' of this Institute was considered equivalent to a Master's degree and was much valued. Agricultural research and education through the early 1950's was, therefore, the responsibility of a multitude of agencies without any central agency for effective coordination.

ATTEMPTS AT ORGANISATIONAL CHANGES

The organisation of research before Independence was recognised to be unsatisfactory, as evidenced by the fact that a number of expert teams were constituted to examine the set up and make recommendations for improvement. The following teams examined this matter in great detail and made very important recommendations:

1. The First Joint Indo-American Team on Agricultural Research and Education (1955).
2. The Second Joint Indo-American Team on Agricultural Education, Research and Extension (1959).
3. The Agricultural Administration Committee (Nalagarh Committee).
4. The Committee for Agricultural Universities Legislation — (Cummings Committee) — 1962.
5. The Agricultural Research Review Team (1963).

The recommendations of many of these teams tended to overlap, primarily because of the slowness in implementation of recommendations at the earlier stages. The last team, which had taken into account the recommendations of previous teams as well as the progress made in the implementation of their recommendations,

emphasised the necessity of having some radical changes if worthwhile results were to be achieved. Based upon the recommendations of this team, it was decided to reorganise agricultural research throughout the country, a process which is still underway.

RE-ORGANISATION OF AGRICULTURAL RESEARCH — THE BACKGROUND

Before analysing the recommendations of the Agricultural Research Review Team (1963) we might examine the agricultural structure in India a decade before this Team was set up.

Authority for Agriculture

The Constitution of India, which came into effect on January 26, 1950, provided for certain functions to be handled by the Union Government exclusively, others to be handled by the states exclusively and certain other functions jointly or concurrently. Promotion of special studies or research, as well as coordination and determination of standards in institutions for higher education or research and scientific and technical institutions, were within the purview of the Union Government. The following items were specifically placed in the State List:

1. Agriculture, including agricultural education and research, protection against pests and prevention of plant diseases.
   (Entry No. 14 — State List)

2. Preservation, protection and improvement of stock and prevention of animal diseases; veterinary training and practice.
   (Entry No. 15 — State List)

The Central Government took much more of the initiative for agricultural research. Though certain State Governments had good agricultural research stations and educational institutions, research was badly neglected in many of the States. Support for research was provided largely by the Government of India, Ministry of Food and Agriculture, through a number of central research institutes, commodity committees and directorates.

Central Research Institutes

The Indian Agricultural Research Institute, established as the Imperial Agricultural Research Institute in 1905 at Pusa in Bihar, and transferred to New Delhi in 1936 after its building was destroyed by the earthquake of 1934, has remained as India's premier agricultural research institute covering a wide range of subjects. In addition to doing both basic and applied research the Institute was a post-graduate training centre and conducted survey and advisory work in a number of fields.

The Indian Veterinary Research Institute, with its main station at Izatnagar (Bareilly), was first established as the Imperial Bacteriological Laboratory at Poona in 1889, and transferred to Mukteswar in 1893. The subsidiary station, established at Izatnagar in 1915, ultimately developed into the main centre with Mukteswar remaining as associate centre. In addition to research, this Institute also had facilities for post-graduate studies leading to the Master's and Doctorate degrees in different

disciplines. It also produced anti-sera and vaccines and provided diagnostic services for animal diseases on a nation-wide basis.

In addition to these two premier institutes in agriculture and animal sciences, the Ministry of Food and Agriculture had a number of other institutes including:

1. The Central Rice Research Institute, Cuttack.
2. The Central Pôtato Research Institute, Simla.
3. The Sugarcane Breeding Institute, Coimbatore.
4. The Central Inland Fisheries Research Institute, Barrackpore.
5. The Central Marine Fisheries Research Institute, Mandapam.

The Indian Dairy Research Institute, originally located at Bangalore was later established as the National Dairy Research Institute at Karnal. The Bangalore campus became a subsidiary of this National Institute which also has developed into a major research institution and will have a centre for post-graduate studies in the near future.

The Indian Council of Agricultural Research

The Indian Council of Agricultural Research (which evolved from the Imperial Council of Agricultural Research set up as a Society under the Societies Registration Act in 1929) had broad aims and objectives, as is evident from the following clauses in its Memorandum of Association:

(a) To undertake, aid, promote and coordinate agricultural and animal husbandry education, research and its application in practice, development and marketing by all means calculated to increase scientific knowledge of the subjects and to secure its adoption in every day practice.

(b) To act as a clearing house of information not only in regard to research but also in regard to agricultural and veterinary matters generally.

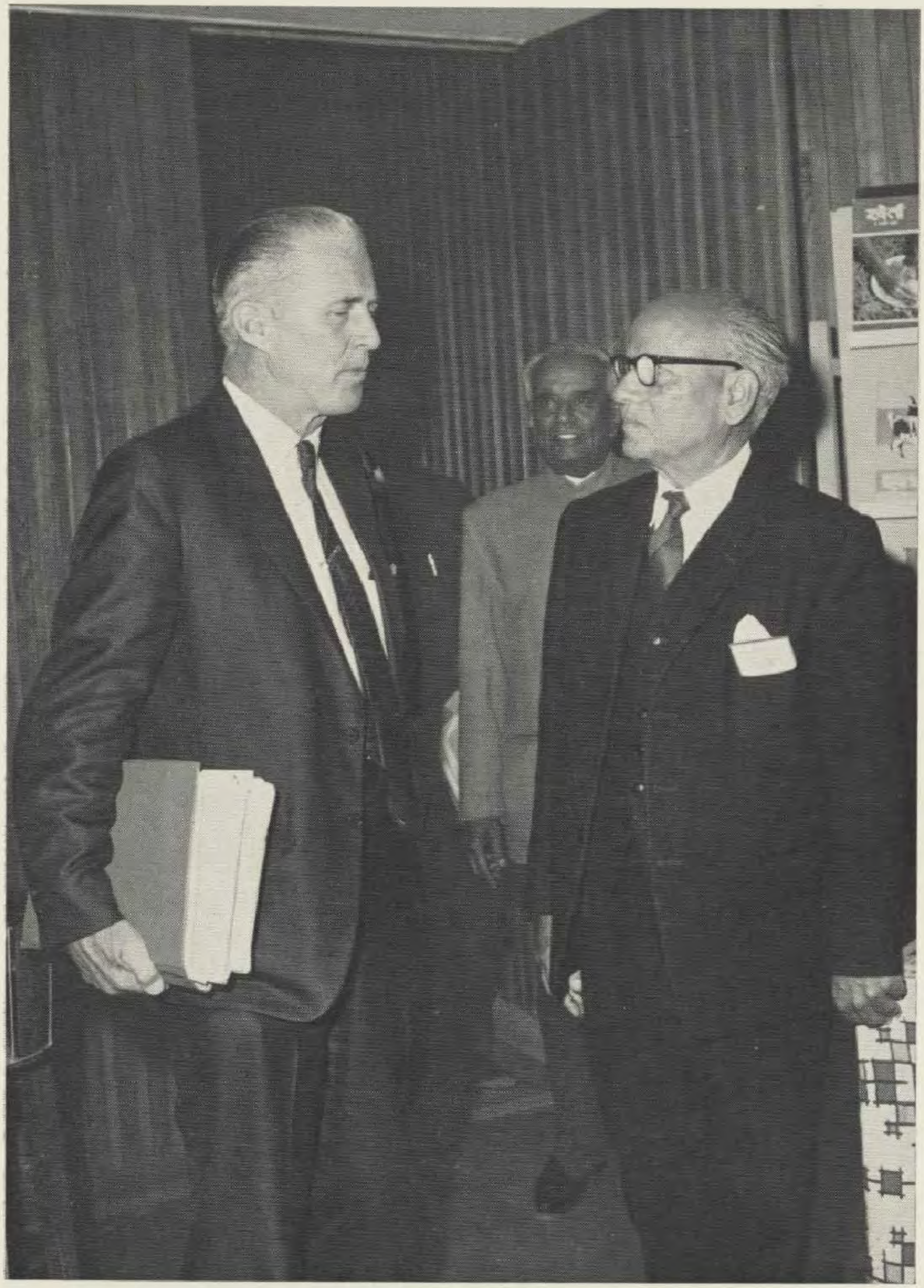
(h) To establish and maintain a research and reference library in pursuance of the objects of the Society with reading and writing rooms and to furnish the same with books, reviews, magazines, newspapers and other publications.

(i) To do all other such things as the Society may consider necessary, incidental or conducive to the attainment of the above objects.

In practice, the Council played a very limited role. It had no control over the Research Institutes which were administered by the Ministry of Food and Agriculture. It did not direct or operate research institutes of its own. The Council gave ad-hoc grants to various research institutes (including the Central Research Institutes), universities and other research organisations.

Central Commodity Committees

A substantial part of the support for research on a number of major crops of commercial importance was provided by the Central Commodity Committees. The first Commodity Committee came into existence in 1921, before the Imperial



Dr. Norman E. Borlaug, Director of wheat research, International Maize and Wheat Improvement Centre — recipient of the Nobel Peace Prize for 1970 — discusses cooperative research with Dr. B. P. Pal, Director General, Indian Council of Agricultural Research. Mr. K. Ramiah observes.

Secretary Arturo Tanco, Jr., Department of Agriculture and Natural Resources, Government of the Philippines, discusses the Philippine experience in applying new technology to boost rice production.

Council of Agricultural Research was established. Committees existed for the following crops:

1. Cotton
2. Sugarcane
3. Tobacco
4. Oilseeds
5. Jute
6. Coconut
7. Lac
8. Arecanut

The Committees were established to promote research, development, extension and marketing. The funds for the committees came from special cesses levied by the Government under the relevant Acts, or by special grants-in-aid given by the Government of India. The Commodity Committees, established to give special attention to problems confronting crops of commercial importance, made significant contributions to technological advances in their respective fields. However, there were a number of serious deficiencies in their operation. The Vice-President of the Indian Council of Agricultural Research was also the President of most of the Commodity Committees. This position changed from time to time so there was a lack of continuity which restricted the ability of ICAR to coordinate the work of the Committees and to avoid duplication of efforts. The fragmentation of support on a crop basis also precluded attention to research on 'non-commodity' problems — in soil management, cropping practices, etc.

Agricultural and Veterinary Colleges

Some of the States had established very good agricultural and veterinary colleges. Though most of the States had such colleges, their work tended to be extremely good in certain fields but extremely deficient in others. Agricultural research received varied degrees of attention, depending upon the resources of the state governments and the attitude of the persons in charge.

Other National Institutes and Laboratories

In addition to the above institutions and organisations which were directly connected with agricultural research, there were also a number of research institutions not associated with the Ministry of Food and Agriculture or with the states which also contributed directly to advancement of agricultural technology. The following institutions are examples:

1. The National Physical Laboratory, New Delhi.
2. The National Chemical Laboratory, Poona.
3. The Central Laboratory for Scientific and Industrial Research, Hyderabad.
4. The Indian Institute of Science, Bangalore.
5. The School of Tropical Medicine, Calcutta.
6. The Indian Institute of Hygiene and Public Health, Calcutta.

The Indian Council of Agricultural Research recognised the value of these institutions for conducting research in specialised fields related to agriculture and had provided funds for support of special research projects.

It is evident from the foregoing that a large number of central and state agencies were concerned with agricultural research and each was, in its own way, trying to contribute to advancement of agricultural science and technology. The First Indo-American Team (1955) concluded that neither the Indian Agricultural Research Institute nor the Indian Veterinary Research Institute was in a position at that time to function effectively as either leaders in agricultural, veterinary or animal husbandry research in India, or to coordinate the research programmes of the states and the centre on a regional or national basis. All of these institutes were treated as subordinate, separate offices of the Ministry of Food and Agriculture and were individually responsible to different sections or administrative heads in the Ministry. The Team pointed out that not even the research supported directly by the Ministry was subject to adequate internal coordination (page 7 of the Report). The position had not changed considerably when the Second Joint Indo-American Team reviewed agricultural research and education in 1959.

The Agricultural Universities

One development which was to radically change the course of events in the states took place during the Second Five-Year Plan. This was the establishment of the Agricultural University at Pantnagar, in Uttar Pradesh. The seed for this was contained in the Report of the University Education Commission which was headed by the eminent Indian scholar and educationist Dr. S. Radhakrishnan. The First Joint Indo-American Team also endorsed the recommendation of the University Education Commission that a rural university should include a ring of small resident, under-graduate colleges with specialised and university facilities at its centre. For the complete development of a rural university the Team envisaged the setting up initially, on the same campus, of a college of agriculture and a college of veterinary science, to which should be added in due course a college of home science, a college of 'applied' liberal arts and science, a college of technology (using the term in the broad sense of engineering and industries) and with essential laboratories for the students. The Team recommended that the development of rural universities should be encouraged by substantial grants-in-aid from the Centre so that they would be autonomous and efficiently operated.

Only the State of Uttar Pradesh came forward during the Second Five-Year Plan to establish an agricultural university. The State Government made a large tract of land available for the university with the idea that the income from the land would help to support the university. The Indian Council of Agricultural Research gave massive assistance for the development of the Agricultural University. The University also had full cooperation and support from the USAID and a pattern was developed under which the Agricultural University had the collaboration of a sister university in the United States, the University of Illinois.

The establishment of the U. P. Agricultural University was a turning point in agricultural education in India. More agricultural universities came to be established in different States in the following order:

1. University of Udaipur, Udaipur (as Rajasthan Agricultural University) July, 1962.

2. Orissa University of Agriculture and Technology, Bhubaneswar. August 1962.
3. Punjab Agricultural University, Ludhiana. October, 1962.

The Punjab Agricultural University, although started in 1962 as the fourth agricultural university in the country, made remarkable progress in a very short time. The Uttar Pradesh Agricultural University did not attempt to take over the state-wide responsibility for research from the State Department of Agriculture nor did the state government accept this proposition from the beginning. The Punjab State Government, however, handed over the entire responsibility for research and education in agriculture and animal sciences to the newly established Punjab Agricultural University. The University was also given a prominent role in extension education. Those in charge tried to build a good working relationship between the staff of the university and the extension workers under the technical directorates dealing with agriculture and animal husbandry.

The universities which were subsequently established tried to use the Uttar Pradesh Agricultural University and the Punjab Agricultural University as models. In certain cases implementation of other universities was slow because of the lack of commitment and lack of full support from the state governments.

THE RECOMMENDATIONS OF THE AGRICULTURAL RESEARCH REVIEW TEAM (1963)

It was against this background that the Government of India decided to appoint the Agricultural Research Review Team (1963) with very wide terms of reference. The Team comprised eminent scientists from India, the United Kingdom and the United States. The First and Second Joint Indo-American Teams had been appointed to suggest measures for improvement of facilities and programmes in agricultural education and research. The Agricultural Research Review Team was directed to assess the previous recommendations and to furnish further proposals and suggestions for improvement of the organisation, administration and conduct of agricultural research programmes of national, regional and local importance. The following were the terms of reference of the Team:

1. To consult various individuals and groups at the Centre, in the States and in representative existing research institutions with a view to obtaining a first hand appraisal of the problems being encountered which limit attainment of maximum efficiency and effectiveness in the utilisation of funds and talents devoted to research on problems concerned with agricultural improvements.
2. To appraise the merits of proposals of the First and Second Indo-American Teams with respect to changes in the organisation and administration of agricultural research programmes of the Centre and the States and the problems encountered or likely to be faced in implementing these proposals.
3. To suggest changes required in the organisation to bring about a greater coordination between the central research institutions and the state research institutions.
4. To prepare detailed proposals and suggestions for the improvement in the effectiveness of organisation, administration and conduct of agricultural research programmes of national, regional and local importance

and significance which can be expected to meet the real needs for substantial and sustained improvements in agricultural production and progress.

5. To suggest steps required to orientate research problems in the field, particularly in the state research institutions and to ensure an adequate contact with the agricultural extension worker to bring about two way traffic between the farmer and the research institution.

6. To recommend suitable methods of publication of research all over India so that each research worker is in touch with the work going on in his discipline in that subject.

The Government of India was aware of the new interest in research and education in many States after the establishment of agricultural universities and also appreciative of the good work being done in many of the central research institutes.

The Research Team made an extensive tour of the whole country, visited most of the important institutions concerned with agricultural research and education and had discussions with many scientists, administrators and policy makers. They had a full opportunity to assess the strengths and also the deficiencies in programmes. One of the main weaknesses noted was the system of personnel management. The Team felt that recruitment through the Public Services Commission, as for other civil servants, was not suitable for scientific organisations. Similarly, the system whereby scientists had to transfer from one position to another, often abandoning their specialised line of work in order to obtain promotions, was highly inefficient and rudimentary.

Great emphasis was laid by the Team on partnership research programmes between the Centre and the states. The Team recognised that the central institutes and the state research organisations each had an important and vital role to play but emphasised the need for a central agency to coordinate research efforts throughont the country. This would involve the administering of all central research institutes which were either subordinate offices of Government departments or under the central commodity committees. The Central Council should also have a strong extension wing to provide the link between research and the users of research results. The Team recommended that the Chief Executive of the Central Council be an eminent scientist with the designation of Director General. He should be supported at an appropriate level by professional administrators and financial experts and should also be assisted by a number of senior scientists who would supervise the work in various broad disciplines. In addition, the Council should have specialist advisers for all important disciplines to give technical advice in their specific fields.

RE-ORGANISATION OF AGRICULTURAL RESEARCH

Unlike many other reports, the report of the Research Review Team received prompt attention from the Government of India. The Team was appointed on October 31, 1963, and submitted its Report on March 19, 1964.

The Government of India decided to implement the recommendations in about a year's time, with such modifications as were considered necessary. The first step was the reorganisation of the Indian Council of Agricultural Research into a central agency for coordinating, directing and promoting agricultural research and education in the whole country. Dr. B. P. Pal, an eminent agricultural scientist, was appointed the first Director-General.

The Central Institutes

All the central research institutes, which had been under the direct administrative control of the Department of Agriculture or the Department of Food, were transferred to the ICAR and became constituent units of the Council. I am specially using the term 'constituent units' since it is the policy of the Council that institutions doing scientific research should not be organisationally subordinated. The institutes function as the executing arm of the Council and all research programmes undertaken by the Council are executed through the institutes.

The taking over of the central research institutes which were directly administered by the Government of India as subordinate offices presented some difficulties. The reorganised Council was not considered a government department since the idea was to give it more freedom of operation, without many of the constraints imposed upon government departments. Because many employees were apprehensive about losing certain government service safeguards, the Government decided that such safeguards should be given by an Act of Parliament. It also decided that the Council should be declared an institution of national importance. A Bill is to be introduced very shortly in the Parliament for this purpose.

The Commodity Committees

It was decided to abolish all Commodity Committees and to put their research directly under the ICAR. The Commodity Research Institutes were thus made constituent units of the ICAR. Attempts were made to align the large number of ad-hoc research schemes which had been sanctioned by the Commodity Committees with the All-India Coordinated Research Projects. The abolition of the Commodity Committees and transfer of their research work to the Council was completed in less than a year.

Salaries and Personnel Management

From the beginning of the reorganisation, improvement of the working conditions for agricultural scientists has received the attention of the Council and the Government. In India, pay scales of agricultural scientists were ridiculously low compared to those of scientists in other organisations, e.g. the Council of Scientific and Industrial Research and the Atomic Energy Commission. It is, however, recognised that the contribution of agricultural scientists has been second to none. Unfortunately, the country was going through certain emergencies when it was decided to re-organise agricultural research and the Government imposed a general ban on upward revision of pay scales. A special case was made to equalise pay of agricultural scientists with pay scales in other scientific organisations. Progress has been made but this requires further attention.

More important than the revision of pay scales is improved procedures for promotion. This also is receiving further consideration.

A radical change has taken place in methods of recruitment. Selections to all scientific posts (except at very junior levels) were formerly made by the Union Public Service Commission. Following the principle that selections for scientific posts must be made by scientists familiar with the disciplines concerned, the ICAR has arranged for the Head of the Institute or the head of the division concerned

to be fully involved in the selection, either as a member or as Chairman of the selection committee which also includes other scientists.

Similar changes have taken place at the state level. With the Ordinance promulgated by the Government of Tamil Nadu recently, all major States of India have decided to establish agricultural universities. These universities have dispensed with staff selection by the State Service Commissions and are recruiting staff through their own selection committees consisting of scientists and specialists. The interchange of scientists between agricultural universities and with central institutes and the Council is facilitated through these uniform procedures for staff selection.

We are aware that young Indian scientists training abroad are often unwilling to return to India, not only because of comparatively unattractive pay but because of unsatisfactory working conditions. The lack of academic freedom in a laboratory is particularly depressing to the young scientist returning to India after working for a few years in a foreign laboratory. Quoting a distinguished scientist colleague, 'the most important index of academic freedom is the extent of the scientific discussion which goes on in any institution. Academic freedom implies respect for opinions and ideas irrespective of the status of the individual who expresses them'. If the opinion of the junior scientist is seldom respected, after some time he loses the habit of even forming an opinion. India is not the only country where credit for work done by junior scientists is often carried away by his seniors, thus making him a junior partner.

While administrative bureaucracy is built upon the concept of level it is tragic if a scientific bureaucracy is permitted to develop or allowed to continue in research laboratories.

After the reorganisation the Council emphasised that every scientific worker should have a sense of involvement in the research programmes of the Institute. A lead has been taken in this respect by the Indian Agricultural Research Institute and all institutes of the Council now have staff research councils which are expected to meet frequently to discuss their scientific programmes. The effectiveness of such Councils will depend, of course, upon the attitude of the Director and senior scientists in their implementation.

The institutes are now expected to maintain research project files in which names of the scientists in a particular project are specified. Only those who are actively engaged in a particular research project are shown as partners in that project. These steps have improved matters greatly and achieved a much better atmosphere of academic freedom in the Indian Council of Agricultural Research laboratories.

Periodic conferences of directors, senior scientists and administrators of the Council have been helpful in other respects. While the broad policies and priorities in agricultural research are laid down by officers at the highest level, in consultation with the ICAR and the Department of Agriculture, and allocations for research and education must take into consideration the existing resources and constraints, the ICAR is given considerable freedom to develop priorities and programmes. Open discussions involving directors of research programmes and senior scientists who serve as advisers of the Council help to correct cumbersome procedures, faulty delegation of authority, inadequacy of staff, etc.

Partnership in Research — The new concept

So far, I have been speaking about important new developments in the central organisation and institutes, as well as the state institutions. The present strength of agricultural research in India, however, lies in the new sense of partnership between the central and state agencies for attainment of a common national goal. In the Federal Constitution of India, agricultural development and agricultural research are important state subjects but the Union Government can also play a vital role in promoting scientific research and education. In order to achieve full benefits from limited facilities available, and make maximum use of the best talents of the country, irrespective of whether the resources are in a Central Government laboratory or in state research organisation the full coordination of use of all available resources is essential. The principle was fully accepted when the ICAR decided to implement the All-India Coordinated Maize Improvement Project in 1957 with the collaboration of the Rockefeller Foundation. The Foundation had executed an agreement with the Government of India to assist in research for improvement of selected crops and in the establishment of the Post-Graduate School at the Indian Agricultural Research Institute. Through the efforts of the Foundation India was able to assemble a world collection of germplasm of maize, sorghums and millets which is one of the greatest assets for any breeding programme. Rockefeller Foundation scientists worked side by side with Indian scientists in different Central and state research stations. Spectacular results were achieved from the All-India Coordinated Maize Research Project which prompted the ICAR to accept it as a model for All-India Coordinated Research Projects for other important food and commercial crops. Subsequently, this pattern has also been applied to animal sciences research, a field much neglected in the past.

The All-India Coordinated Research Projects formulated by the ICAR provide for effective planning and executing of agricultural research on a national basis. The financing of ad-hoc research schemes in an isolated and uncoordinated manner, as was generally done in the past by the ICAR and the Commodity Committees, was not effective for solution of problems of the country as a whole. The more comprehensive All-India projects are based on the following principles:

(a) Research is problem-oriented.

(b) Research efforts are intensified at selected centres for tackling important problems to support the new strategy of agriculture.

(c) Research is strengthened in a centre where leadership and the desired facilities are available.

In formulating the All-India coordinated research projects, the problem is visualised for the country as a whole. Research centres and sub-centres are located in different parts of the country to meet the needs of distinct agro-climatic zones and regions rather than for individual states.

Efforts are made to consolidate and intensify research at a few selected centres representing different soil and climatic conditions to insure efficient use of limited research resources. The central research institutes and the state agencies (agricultural universities or state departments of agriculture) work as partners so that all efforts are complementary rather than competitive.

Another important feature of the coordinated projects is their multi-disciplinary approach. For example, in a coordinated project for crop improvement where the main emphasis is on breeding of superior varieties, research is simultaneously carried out in agronomy, plant pathology, entomology and biochemistry etc. so that all facets of a problem are tackled. Good team-work amongst the scientists from different disciplines and at different centres is vital to the success of the All-India coordinated research programmes. The project coordinator is an active and capable research scientist. The technical planning is done on an All-India basis at the annual or periodic workshop or meeting of the participating scientists. Many visitors, even those from advanced countries, have been greatly impressed by the effectiveness of the All-India projects.

There are scientific problems which transcend national boundaries as well. In one of the All-India Coordinated Research Project workshops we were privileged to have a few scientists from our neighbouring country, Ceylon. We welcome the participation of scientists from other countries in our workshops on crops or problems of mutual interest. Likewise, our scientists will be happy to visit neighbouring countries to exchange information and plant materials for trial under similar agro-climatic conditions.

REMOVAL OF IMBALANCES

Livestock Research

Research in animal sciences was initiated in this country at the Indian Veterinary Research Institute (IVRI) which was started sixteen years prior to the establishment of the premier Agricultural Research Institute at Pusa. The IVRI had many internationally eminent veterinarians and other scientists working in its laboratories. The famous Dr. Robert Koch visited the Institute in 1897. While working at the Institute Dr. Edward first manufactured the goat tissue culture rinderpest vaccine. It is, however, regretful that the Institute and animal sciences research in India languished for some time. In the efforts to boost agricultural production after Independence little attention was given to animal husbandry or fisheries. Animal science research, including fisheries research, was very much neglected and the IVRI was without a permanent director for many years.

Special attention was paid to animal improvement by the ICAR in the recent reorganisation. The Council now has three important research institutes for animal development and diseases, (1) The Indian Veterinary Research Institute, Izatnagar; (2) The National Dairy Research Institute, Karnal; and (3) The Central Sheep and Wool Research Institute, Malpura. In addition, there are three institutes dealing with fisheries research, (1) The Central Inland Fisheries Research Institute, Barrackpore; (2) The Central Marine Fisheries Research Institute, Cochin; and (3) The Central Institute of Fisheries Technology, Cochin.

All-India Coordinated Projects have been designed for research on all animals and birds of economic importance, cattle, buffaloes, sheep (for mutton and wool) and poultry (for eggs and meat) etc. The research institutes have been strengthened considerably and are now making good progress under the leadership of competent and devoted scientists. Strong centres of animal science research and education have been developed in various agricultural universities, with Hissar and Pantnagar two outstanding examples. The ICAR has allocated Re. 21 Crores for the development of the central institutes and for various coordinated research

projects in this field. This is in addition to the assistance to the agricultural universities and veterinary colleges in their normal development schemes.

Research for Dryland Farming

The more recent results from research laboratories have benefited primarily those farmers who have assured sources of water supply, either from assured rainfall or from irrigation. The Central Arid Zone Research Institute at Jodhpur was established some time ago to serve the needs of farmers in arid regions. The scientists at this Institute and at the IARI, as well as some of the agricultural universities have made important contributions in this field. A special project also has been recently drawn up by the ICAR on dryfarming research.

APPLICATION OF RESEARCH RESULTS

The Indian Council of Agricultural Research is not responsible for extension work at present. The research worker today, however, is not satisfied until the results of his work have reached the farmer and are utilised. National demonstrations have been set up all over the country in which the research workers, in collaboration with extension workers, demonstrate the benefits from research programmes.

APPLIED AND BASIC RESEARCH

It is generally accepted that in a country like India research has to be problem-oriented and problem-solving. Our national research system lays maximum emphasis on applied research. Nevertheless, basic or fundamental research is not neglected but it is confined primarily to certain centres which have the proper facilities. Many of the ICAR institutes depend upon the Indian Agricultural Research Institute and other national institutes for basic and background research.

The minutes recorded by the Agricultural Research Council of the United Kingdom, taking into consideration the recommendations of a working party appointed in May, 1966 to consider the whole forward programme of state-supported agricultural research is relevant in this connection:

> 'The Council has always recognised that effective applied research depends for its success on a continuing flow of new ideas from many sources. Only a small percentage of speculative investigations is likely to produce practical results but that small percentage may lead to major advances and in a few cases to revolutionary ones. Moreover work of this kind attracts some of the most able people into agricultural research and is an essential investment for the future. The Council has therefore readily endorsed the Working Party's recommendation that the proportion of the ARC's resources devoted to speculative research in the next ten years should be maintained at least at the present level.'

CONCLUSION

Efforts to build up and further strengthen a national agricultural research system in which the Centre and the states are partners must be continuous and must have a sense of purpose. The reorganisation of the Indian Council of Agricultural Research is only partially complete. It has always been emphasised by management experts that an organisation must adjust to constant changes, external or internal, economic or political, technological or environmental. No organisation

can remain static if it is to retain its vigour and vitality. Those who deal with biological sciences know that growth is a sign of life, and when growth ceases the living organism is on the decline.

I should like to conclude by suggesting that the scientists and scientific organisations from the countries who have joined this Seminar should also try to achieve greater mutual collaboration in their important agricultural research which is contributing to the peace and happiness of mankind.

Agricultural Research in Indonesia

SUTARDI MANGUNDOJO

Chairman of the Committee for Establishing the Indonesian Agricultural Research Organisation, Djakarta, Indonesia.

'sLands Plantentuin (the State Botanical Garden) established in 1817 by C. G. C. Reinwardt was the pioneer among the institutes of agricultural research which now exist in Indonesia. Agricultural research was first directed to a specific field by establishment of a department, namely Cultuurtuin (Economic Garden) in 1876.

Many crop plants introduced by Cultuurtuin later became important as export crops. After intensive research and testing, cultivation of these plants was taken over by estate corporations. These estates grew and developed so rapidly that Cultuurtuin alone could not handle the research services for all of the estate problems. This resulted in estates themselves establishing experimental stations on specific crops. The sugarcane industry was the first to establish a private experimental station when a virus disease ruined the sugarcane crop in 1883–1884. Later, experimental stations were established for coffee, tea, cocoa, tobacco and other crops. The development of these experimental stations followed the world market demands for various estate products.

In 1918 Cultuurtuin was separated from 'sLand Plantentuin, and was placed under the Ministry of Agriculture, Industry and Trade. Cultuurtuin was then renamed Het Algemeen Proefstation voor de Landbouw (the General Agricultural Research Station). Research at this station was limited to crops. Veeartsenijkundig Institut was established in 1908 for veterinary research; Boschbouw Proefstation in 1913 for forestry research; Laboratorium voor de Binnenvisserij in 1923 for fishery research; Laboratorium voor Agrogeologie en Grondenonderzoek was established in 1905 for research on agrogeology; and Bureau voor Landbouw en Handels-analyses established in 1909 for research in chemistry. These experimental stations worked separately under the control of the Ministry of Agriculture, Industry and Trade.

It is important to review two different time periods in order to understand the development of Agricultural Research in Indonesia; first, the period after the outbreak of war in Europe in 1939 and before the Pacific War in 1941; second, the period from 1941 to 1969 when experimental stations faced many changes in organisation. After these periods, the Government of Indonesia felt that re-evaluation and improvement of organisation were needed to meet and support the agricultural development programmes of REPELITA 1, the first Five Year Development Plan.

Recommendations from the Joint Agricultural Research Survey Team of 1969 and their implementation will be presented and discussed at the end of this paper.

AGRICULTURAL RESEARCH AT THE BEGINNING OF THE PACIFIC WAR, 1941

In 1939 the German occupation of the Netherlands severed communications between Nederlands Indie (Indonesia) and the Netherlands. Activities on research were intensified, in agriculture in particular, to meet wartime demands.

By 1941, agricultural research had progressed rapidly and reached a peak never attained before. At that time there were five state research institutes, and eight research institutes owned by big private estates *(Appendix I)*. The total number of research workers was 156, of whom 86 worked in the state research institutes and the remaining were employed in private experimental stations. Among these was only one Indonesian research worker. Other Indonesians held positions as research assistants.

The private research stations were sponsored by the association of big plantation companies, except N.I.I.R.O., which was financed by the rubber funds (cess funds). Some of the big estates owned land-bouwkundige afdeeling (agronomy divisions) which conducted research projects independently from the listed research institutes.

There were several of those research institutes which achieved worldwide scientific reputations. Their excellent results achieved for Indonesia a high place in international trade as an exporter of sugar, rubber, copra, quinine, kapok and other crops. The pride in their past achievements have, however, created continuing difficulties in cooperation and coordination.

AGRICULTURAL RESEARCH IN 1941 — 1969

Indonesia faced many changes in the structure of its society and in Government from 1941 to 1969. During the Pacific War, after the Nederlands Indie army surrendered to the Japanese, the latter occupied Indonesia until 1945. The key posts in the research institutes were held by Japanese and the Dutch research workers were lodged in prison camps. In 1943 almost all Dutch scientists were prisoners of war and the Indonesian research assistants were gradually promoted to important positions in the research institutes.

The number of research workers with academic training was not enlarged during the occupation because the Faculty of Agriculture was closed after the Japanese invasion. The Indonesian senior staff members were ordered to cooperate with their Japanese bosses in the research institutes. When the war ended, and particularly after the proclamation of Indonesian Independence, all of the research institutes were taken over by force from the Japanese. The Indonesian struggle for independence continued from 1945 until 1950 and during this period not much research was done. The leaders of the Institutes, in Bogor, Pasuruan, Medan, etc. and their personnel had to move continuously from place to place to avoid the Dutch forces. They were scattered to many locations during this period.

In 1950, after Indonesian sovereignty was recognised by the U.N.O., the leaders of the institutes as well as most of their staff returned to their former residences. After diplomatic relations between Indonesia and the Netherlands were re-established many Dutch research workers returned to Indonesia to work for the Indonesian government at their former research institutes. Their research results were again published regularly in scientific journals, either in Indonesian or in English, and distributed to the international scientific world.

During the period from 1950 to 1960, a calm and undisturbed time, many Indonesian research workers from the institutes obtained academic degrees and gained research experience either at home or overseas.

After 1950, the development of colleges of agriculture proceeded rapidly. Post high-school education institutions, called *Akademi,* were established. These akademis were formed to educate experienced non-graduate staff in research institutes for two to three years. On completion of this course the members were expected to fill positions formerly held by academically qualified research workers and other posts in government. The development of education at university level was also good and the faculties of agriculture and veterinary science at Bogor and Jogjakarta grew rapidly.

This development declined in 1957 due to political conflicts between Indonesia and the Netherlands. The Dutch scientists left Indonesia gradually but before the Indonesian scientists were qualified to take over the positions held by the Dutch.

The internal political situation in Indonesia deteriorated after 1960 and was at its worst during the communist rebellion in October 1965. The frequent and rapid changes in government administration seriously affected the research institutes. No continuity in leadership and planning existed in the institutes due to the frequent reorganisations. The fragmentation of institutes, administrated by different ministries, caused an unnecessary re-distribution of the small number of research workers to many separate places. (*See Appendices II and III*). The administrative personnel increased in numbers and created a serious imbalance with the scientific personnel.

This unfavourable situation was accelerated by uncontrolled inflation which caused a set-back in the economical situation and seriously curtailed agricultural research.

Appendix IV shows the list of Universities and faculties of agriculture. It is interesting to note that at the present time there is almost one college of agriculture in each province in the country.

THE JOINT AGRICULTURAL RESEARCH SURVEY TEAM'S RECOMMENDATIONS AND THEIR IMPLEMENTATION

The fragmentation of the research institutes continued until Indonesia had an administration with almost a hundred cabinet ministers. At that time the agricultural affairs were handled by four different ministries. The effect of this fragmentation is still felt today although all of the agricultural activities have been placed under one administration from 1968.

In 1969, when REPELITA step 1 began, there was deep concern over the need to re-evaluate and improve the agricultural research organisation to furnish more effective support for agricultural development.

In early 1969, the Government of Indonesia with the assistance of USAID, established an Agricultural Research Survey Team. The team consisted of 11 Indonesians, 5 members from the U.S.A., 1 member from India, and 1 from the Netherlands. The main task of this team was to make recommendations to the Government of Indonesia to guide establishment of a better system and organisation of agricultural research in Indonesia.

The problems Indonesia faced in the past, as discussed above, may be summarised as follows:

1. There was no council or body with authority to determine national policy on agricultural research. This created imbalanced sectorial research activities.

2. The fragmentation of the agricultural research institutes which precluded coordination among the institutes, and between the institutes and the colleges of agriculture.

3. The unsettled status of the former private plantation research institutes.

4. Excessive bureaucracy in channelling financial support from the government for research, with rigid financial administration by the government.

5. Low salaries for research workers so that it was not possible for the institute to hire qualified personnel.

6. The consequence of ten years of political instability which caused a serious deterioration in the working environment for scientists.

To solve these problems the Joint Team recommended the establishment of a national organisation and system of research as follows:

(a) The setting up of an Indonesian Agricultural Research Organisation at the national level with a semi-autonomous status.

(b) The grouping together of the various central research institutes on agriculture, animal husbandry, forestry and fisheries into a strong national research centre.

(c) The launching of a number of national coordinated research projects.

(d) The building-up of a national cadre of well-trained, well-paid, and fully-supported scientists.

(e) The decentralisation of agricultural research in the country by establishing and energising a chain of experiment stations to cover adequately the regional and provincial needs of agricultural research.

(f) The forging of strong links between research, education and extension.

(g) The achievement of balance and coordination of foreign-assisted programmes and projects.

The existing research institutes are not only under different ministries but also have different legal status (see *Appendices II, III* and *IV*). The present organisational structure of the Ministry of Agriculture is highly compartmented (see *Appendix V*) and it is most difficult to organically unite the leadership of the separate research institutes within the Ministry. A semi-autonomous status of the State Institutes must be achieved through complicated legislation; there is no simple means to accomplish this through parliament.

One initial approach to achieve the goal of a more effective research system is to establish a council to assist the Minister of Agriculture to determine national policies for agriculture research. The members of this council should consist of the Directors General or other high level officials from departments, or from non-

departmental organisations of the same level as the department, concerned with agricultural affairs. The council should also include some senior research workers as members.

The difference in status between the state and private research institutes makes it necessary to divide the council into sub-groups in carrying out the policy programme, one for food, one for plantation crops, and one for forestry.

The grouping of the various research institutes iuto a strong Indonesian Agricultural Research Organisation, as proposed by the Joint Team, is difficult to achieve at this time. The research institutes have been re-organised so many times during 1960–1968, that an effort to re-organise them again would be considered just another disruption so true unification would be questionable.

A proposal by the Joint Team to establish a national coordinated research project (N.C.R.P.) could help create a sound pattern for joint activities and co-ordination. The N.C.R.P. can be carried out without any substantial change in organisation of the institutions participating in the joint effort. The N.C.R.P. can concentrate all available manpower, facilities and funds to one high priority goal important for the development of the country. The interdisciplinary approach will bring a great deal of improvement in many fields and level of activities. Through the N.C.R.P. we can also have better cooperation between research, extension and education. Foreign aid and assistance could also be coordinated more effectively.

In July 1970 a National Coordinated Rice Research Programme was set up as a pilot project. This project was chosen because self-sufficiency in rice, the staple food in Indonesia, is the main programme of REPELITA 1. The valuable assistance from Dr. S. V. S. Shastry of India in this effort is highly appreciated. With his help much misunderstanding concerning the organisation and functioning of the project has been minimised. The National Rice Research Programme's goal is to synchronise all activities in rice research throughout the country. The cooperation in rice research is carried out on a voluntary basis and is conducted by a technical group. This plan has obtained excellent response and the programme has proceeded very well. At the end of March 1971 a workshop will be held to discuss the results obtained since July 1970 and to review plans for the next paddy growing season.

The Joint Team's recommendation on the building of a national cadre of well-trained, well-paid and fully-supported scientists can be started only in the semi-government estate research institutes which, because these have autonomous status, are not tied up to strict Government fiscal regulations. The research workers would be adequately paid, funds could be provided in adequate amounts and with the necessary flexibility.

The state research institutes still face unsettled financial difficulties. Although since the first REPELITA 1 year (1969) the budget for rehabilitation and operation was substantially increased, the availability and spending regulations remain too strict. The very low salaries make it impossible to attract well-qualified personnel. Simultaneously many of the experienced qualified research workers have resigned from civil service for employment in the private industries which offer multiple income.

To stimulate cooperation and coordination an inventory on research workers and research projects has been started which will soon be published. Summaries of publications and reports of significant research work also are being collected and will be published. Financial difficulties limited the distribution of these publications and reports in the last decade. Publication of scientific papers is now stimulated by providing better financial support.

Not much has been achieved since the Joint Agricultural Research Survey Team terminated its assignment in July 1970. Only one fundamental goal has been reached, namely the idea of the Joint Team concerning the importance of problem oriented agriculture research has been appreciated and accepted by many groups as a revision of the 'Ivory tower' concept, which was stamped in our minds by the Dutch through their colonial system. The President of the Republic of Indonesia issued a formal instruction, in August 1970, that research and survey work has to be carried out in a joint effort by all relevant organisations in the country, regardless of the administrative authority.

We hope that public opinion, including attitudes of scientists, will soon mature to enable full application of the recommendations which were submitted by the Joint Team to the Indonesian Government.

APPENDIX I

LIST OF AGRICULTURAL RESEARCH INSTITUTES IN SEPTEMBER 1941

Ministry of Agriculture, Industry and Trade

1. General Agricultural Research Station, Bogor
2. Veterinary Research Institute, Bogor
3. Forestry Research Station, Bogor
4. Division of Inland Fisheries, Bogor
5. Division of Chemical and Technological Research, Bogor

Research Institutes for Estate Crops (Private Institutions)

6. West Java Research Station, (tea, quinine, rubber), Bogor
7. Nederlands — Indisch Institute for Rubber Research (rubber technology), Bogor
8. Central and East Java Research Station (coffee, cocoa), Malang
9. Besoeki Research Station (rubber, tobacco), Djember
10. Research Station for the Java sugarcane industry, Pasuruan
11. General Research Station of the A.V.R.O.S. (Rubber, tea, palm oil), Medan
12. Research Station Deli (tobacco), Medan
13. Research Station for Vorstenlands tobacco, Klaten

APPENDIX II

LIST OF STATE RESEARCH INSTITUTES RELATING TO AGRICULTURE, IN JULY 1969

Ministry of Agriculture

Directorate General of *Agriculture*

1. Central Research Institute for Agriculture, Bogor
2. Soil Research Institute, Bogor
3. Horticultural Research Institute, Djakarta

Directorate General of *Forestry*

4. Forest Research Institute, Bogor
5. Forest Products Research Institute, Bogor
6. Institute for Chemical Research of Forest Products, Bogor
7. Forest Exploitation Research Institute, Bogor

Directorate General of *Fisheries*

8. Research Institute for Inland Fisheries, Bogor
9. Research Institute of Marine Fisheries, Djakarta
10. Institute for Fisheries Boats Technology, Djakarta
11. Institute of Fish Technology, Djakarta

Directorate General of *Animal Husbandry*

12. Animal Husbandry Research Institute, Bogor
13. Animal Diseases Research Institute, Bogor
14. Research Institute for Animal Virus Diseases, Surabaja

Directorate General of *Estate Crops*

15. Research Institute for Industrial Crops, Bogor

Ministry of Health

16. Nutrition Research Institute, Bogor and Djakarta

Indonesian Institute of Sciences

17. National Biological Institute, Bogor

Indonesian Atomic Energy Agency

18. Central Research Institute, Pasar Djum'at, Djakarta

APPENDIX III

LIST OF RESEARCH INSTITUTES FOR ESTATE CROPS, IN SEPTEMBER 1970

No.	Name	Owned by	Financed by	Crops
1.	Research Institute for Estate Crops, Bogor		Cess	rubber, tea, coffee, quinine, tobacco, cocoa
2.	Research Institute of the Sumatra Planters Assoc., Medan		Cess	rubber, palm oil, tea, cocoa, food crops
3.	Agric. Div. of the Deli Tobacco Plantation, Medan	P.N.P. IX	P.N.P. IX	tobacco
4.	Sugar Experimental Station, Pasuruan	P.N.P. (sugar)	P.N.P. (sugar)	sugar
5.	Rubber Research Centre	P.N.P. (I—V)	P.N.P. (I—V)	rubber
6.	Marihat Research Centre	P.N.P. I, II, VI—VIII	P.N.P. I, II, VI—VIII	palm oil, tea, cocoa
7.	Tjinjiruan Research Centre	P.N.P.(7)	P.N.P.(7)	tea, quinine
8.	Getas Rubber Research Centre	P.N.P.(7)	P.N.P.(7)	rubber
9.	Research Division P.N.P. XIX, Klatan	P.N.P.XIX	P.N.P.XIX	tobacco
10.	Research Division P.N.P.XXII, Djember	P.N.P.XXII	P.N.P.XXII	tobacco
11.	Academy for Estate Crops Min. Agric., Jogjakarta	(autonomous)	all P.N.P.	sugar

P.N.P. = Government Estate Enterprise
(7) = seven in number

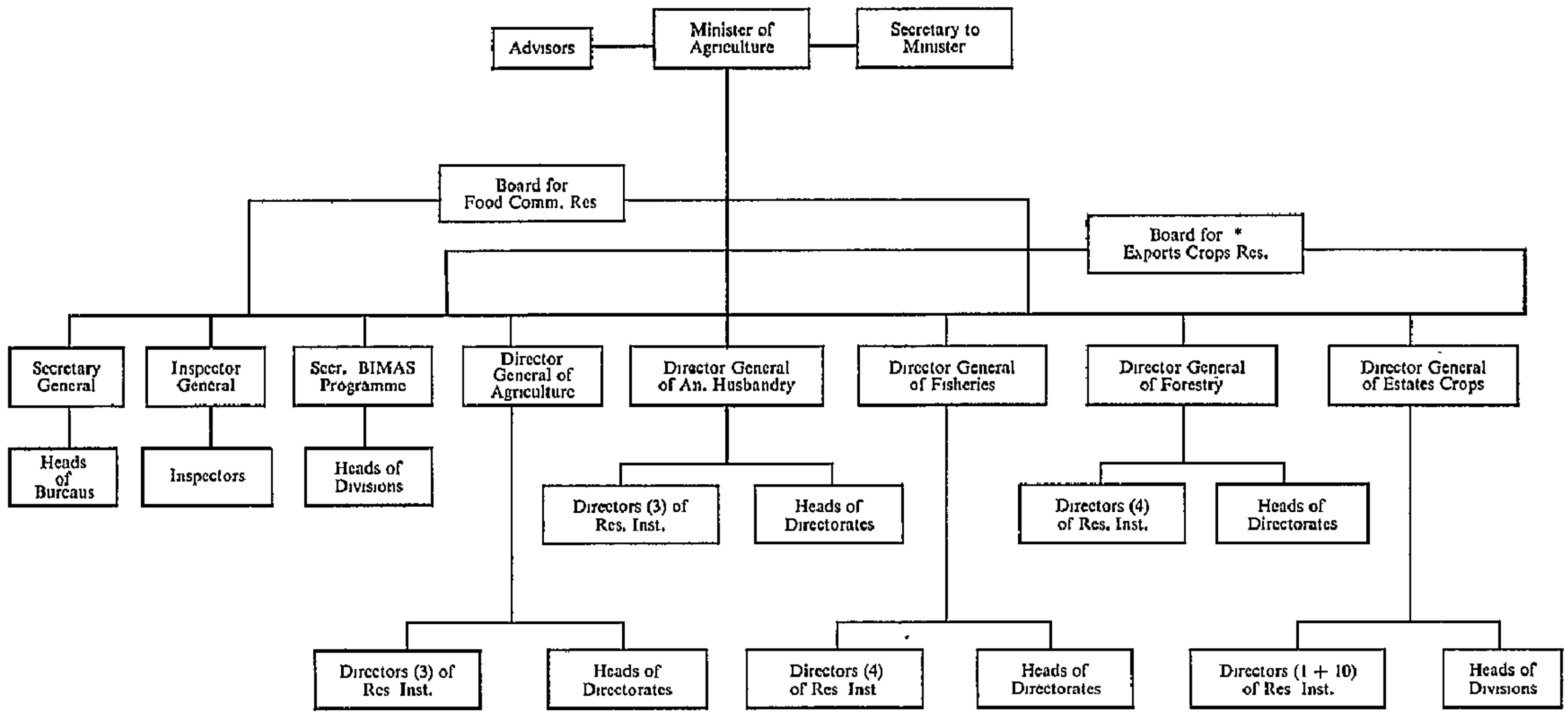
APPENDIX IV

LIST OF FACULTIES OF AGRICULTURAL SCIENCES (MINISTRY OF EDUCATION)
LOCATION AND YEAR OF ESTABLISHMENT

	Agric.	V.M.	An.H.	Forest	Fish	Tech.M.
1. Gadjah Mada, Jogjakarta	1946	1946	1969	1963	—	1963
2. I.P.B. Bogor	1941	1948	1963	1963	1963	1964
3. Sijiah Kuala, Banda Atjeh	1962	—1961††—		—	—	—
4. Sumatra Utara, Medan	1957	—	—	—	—	—
5. Andalas, Padang	1956	—	1963	—	—	—
6. Riau, Pakanbaru	—	—	—	—	1965	—
7. Telanaipura, Djambi	1963	—	1963	—	—	—
8. Sriwidjaja, Palembang	1962	—	—	—	—	—
9. Padjadjaran, Bandung	1957	—	1963	—	—	—
10. Djen. Sudirman, Purwokerto	1963	—	1963	—	—	—
11. Diponegoro, Semarang	—	—	1963	—	—	—
12. Brawidjaja, Malang	1961	—1963††—		1965 (majoring)	1963 (majoring; marine-fishery)	—
13. Djember, Djember	1965	—	—	—	—	—
14. Udayana, Bali	1965	—	1962	—	—	—
15. Hasanuddin, Makasar	1962	—	1963	—	—	—
16. Sam Ratulangi, Menado	1961	—	1962	—	1965	—
17. Lambung Mangkurat, Bandjar Baru	1961	—	—	1964	1964	—
18. Dwikora, Pontianak	1963	—	—	—	—	—
19. Mulawarman, Samarinda	1962	—	—	1962 (majoring)	—	—
20. Pattimura, Ambon	1963	—	1963	—	—	—
21. Tjenderawasih, Manokwari	1963	—	1962	1962	—	—
22. Nusa Tenggara, Kupang	1962	—	1962	—	—	—
23. Kalimantan Tengah, Palangka Raya	1965	—	—	1965	—	—
24. Nusa Tenggara, Lombok	1963	—	1967	—	—	—
	22	2	2 14	7	5	2

†† vet. med. & an. husb.
Agric. = Agriculture
V.M. = Vet. medicine
An.H. = Animal Husbandry
Forest = Forestry
Fish. = Fishery
Techn.M. = Agricultural Technology and Mechanisation.

ORGANISATION CHART, MINISTRY OF AGRICULTURE



* Established
April 1971

The Tropical Agriculture Research Centre—Japan

NOBURU YAMADA

Director, Tropical Agriculture Research Centre, Ministry of Agriculture and Forestry, Tokyo, Japan.

HISTORICAL BACKGROUND

The Ministry of Agriculture and Forestry of Japan launched the tropical agriculture research programme in 1966 with the objective to initiate research service to tropical agriculture as one means of Japan's long-cherished desire to contribute to the development of improved agricultural technology in tropical and sub-tropical regions of the world. For the time being full attention is directed toward Southeast Asia, including India and Pakistan.

Immediately after the establishment of this research programme the Ministry instituted the Tropical Agriculture Research Office in the Agriculture, Forestry and Fisheries Research Council and launched the following research and information service with Mr. S. Hoshide as the head of the Office:

1. Sending survey teams to countries in Southeast Asia to study various problems in tropical agriculture.

2. Sending researchers to those countries to carry out joint research projects in cooperation with local scientists.

3. Holding international symposia on important problems of common interest.

4. Inviting research fellows from abroad to conduct joint research with Japanese staff.

5. Inviting senior research supervisors or senior research administrators to Japan to exchange technical informations and views and to promote mutual understanding and cooperation.

6. Publication of research documents and information service.

After the elapse of five years since the establishment of the tropical agriculture research programme the Ministry of Agriculture and Forestry evaluated the achievement. In the light of the mounting need to promote improvement of agricultural technology of Asian countries as well as to comply with Japan's ever-increasing

obligation to further cooperate with her neighbours, the Tropical Agriculture Research Centre was inaugurated in June, 1970 to further strengthen and expand the tropical agriculture research programme. Although the Centre has taken over the business of the former Tropical Agriculture Research Office it is an entirely new and independent research institution under the jurisdiction of the Ministry of Agriculture and Forestry, fully delegated to carry out the objectives and principles as set forth at the start of tropical agriculture research.

ORGANISATION AND PERSONNEL

The present organisation structure of the Centre is as follows:

	No. of personnel
Director: Noburu Yamada	
Planning and Coordination Division	6
Chief, Sadao Hatta, in charge of: 1. Planning and coordination of research; 2. Documentation and information services; 3. Training service	
Research Division	38
Chief, Kotaro Nagai, in charge of: Implementation of research programme	
Okinawa Branch	10
Chief, Toshio Kodama, in charge of: Research on sub-tropical agriculture including agriculture of Okinawa Islands	
General Affairs Section	4
Accounting Section	4
	63 in total

TROPICAL AGRICULTURE RESEARCH PROGRAMME

The chief aim of the programme is to contribute to the agricultural development of tropical Asia by conducting cooperative or joint research with local scientists in tropical Asian countries to solve various important problems and improve agricultural technology. The research covers a wide sector — breeding, agronomy, pathology, entomology, agricultural engineering, agricultural machinery on rice, upland crops, horticultural crops and industrial crops as well as forestry, animal industry and veterinary science.

To ensure the ultimate achievement of these overall objectives the following activities are carried out by the Centre.

Fact-finding Surveys

To keep pace with recent trends in agricultural development, to identify major technical problems to be solved for future development and to explore the possibility of cooperative or joint research, experts in different fields are sent to various countries.

Cooperative or Joint Research Projects

Since the Centre does not have its own research facilities abroad it sends its scientists to research institutions in other countries to engage in research projects in cooperation with the scientists in those institutions.

The researchers to be dispatched abroad are classified into long-term and short-term visiting scientists.

The term of long-term visiting scientists is, as a rule, two years and for short-term visiting scientist from three to six months according to the nature of their research work. The Centre pays all the costs for travel, subsistence, scientific equipment and supplies required for their research.

The research institution which accepts the visiting scientist is requested to provide the necessary experimental fields, laboratory space, equipment and instruments for the cooperative project.

International Symposia

International symposia have been held each year since 1968, as shown in the *Appendix*. The objective is to mutually study technical problems of common interest for the scientists in tropical Asian countries.

Invitations to Senior Supervisors and Senior Research Administrators to Visit Japan

To ensure the promotion of mutual understanding of our cooperative programmes and to have the opportunity to discuss problems related to the operation and future direction of the Programme's activities the Centre invites senior supervisors or research administrators to Japan with all the travelling and subsistence expenses paid by the Centre.

Invitation to counterpart scientists to visit Japan

If any research project jointly undertaken with scientists abroad needs further study, the Centre offers an invitation to the counterpart researcher to come to Japan to continue his work at a suitable Japanese research institution. In such a case all available equipment and facilities are at his disposal.

Information Services

The following information services are undertaken by the Centre:

1. Library: collecting books, pamphlets, scientific papers and journals related to tropical agriculture;
2. Publication of:
    (a) Japan Agriculture Research Quarterly (JARQ), a publication in English reporting research findings and practical experiences obtained in Japan;
    (b) Nekken-Shuho Bulletin of Tropical Agriculture Research Centre (in Japanese) containing general information on tropical agriculture for Japanese readers.
    (c) Tropical Agriculture Research Series, the proceedings of International Symposia held by the Centre.

No. 1 Rice Diseases and their Control by Growing Resistent Varieties and Other Measures.

No. 2 Symposium on Maize Production in Southeast Asia — Present Situation and Future Problems

No. 3 Symposium on Optimisation of Fertiliser Effect in Rice Cultivation

(d) Non-periodical publications
Reports of Survey Missions (in Japanese)
Technical Bulletins (in English) containing scientific reports on research by the Centre.

Group Training for Rice Research Workers

The Overseas Technical Cooperation Agency (OTCA) is a Semi-Government institution in charge of over-all programmes for Japan's technical cooperation. However, in the case of rice research the Centre is charged with the actual training operation, at the Central Agricultural Experiment Station at Konosu, Saitama Prefecture, about 50 km to the north of Tokyo.

About 10 trainees attend the course each year for the period of six months from May to October.

Application for this training programme should be made to the OTCA through the Japanese Embassy in the respective country.

APPENDIX

INTERNATIONAL SYMPOSIA

Year	*Subject*	*Date*	*Participants from*
1967	Rice Diseases and Their Control by Growing Resistant Varieties and Other Measures	September 25 — October 1	Ceylon, India, Indonesia, Malaysia, Pakistan, Philippines, Taiwan, Thailand, IRRI
1968	Maize Production in Southeast Asia — Present Situation and Future Problems	September 2–8	India, Indonesia, Pakistan, Philippines, Taiwan, Thailand, Asia maize centre
1969	Optimisation of Fertiliser Effect in Rice Cultivation	September 8–13	Australia, Ceylon, India, Indonesia, Malaysia, Pakistan, Philippines, Taiwan, Thailand, IRRI
1970	Farm Mechanisation	October 12–17	India, Indonesia, Malaysia, Pakistan, Philippines, Taiwan, Thailand, Vietnam, IRRI
1971	Rice Insects (held jointly with FAO/IAEA Coordination Meeting of Research Contractors on Rice Insects for 1971)	July 19–24	Ceylon, India, Indonesia, Korea, Malaysia, Pakistan, Philippines, Taiwan, Thailand, Vietnam, IRRI

Agricultural Research in Korea

IN HWAN KIM

Administrator, Office of Rural Development, Ministry of Agriculture and Forestry, Suwon.

The Office of Rural Development (ORD), with main headquarters at Suwon, Korea is charged with the modernisation of agricultural research. This programme began over half a century ago. The major goal of ORD is to implement government agricultural policies of: (a) self sufficiency in food production, (b) increasing farm income, (c) farm mechanisation, and (d) crop diversification.

The Office of Rural Development is under the administrative control of the Ministry of Agriculture and Forestry but enjoys considerable autonomy and flexibility in planning and implementing research programmes.

HISTORY OF AGRICULTURAL RESEARCH IN KOREA

1905–1945

A modest beginning of organised research dates back to 1905 when an agricultural demonstration farm, under the direction of the Ministry of Agriculture and Commerce, was established at Seoul. This station was the only farm conducting agricultural research in Korea. In 1906 the station was moved to its present location in Suwon and at the same time an agricultural school was founded near the farm. The purpose of having the research farm was to obtain basic data for farming and to introduce modern agricultural farming techniques to Korean farmers. In 1929, the farm was renamed the Agricultural Experiment Station and several branch stations were established in different localities.

1946–1956

In 1946, the station was renamed the Central Agricultural Experiment Station. The Central Livestock and Horticulture Institutes were established in 1952 and 1953 respectively. Research during the decade included a systematic listing of various crop varieties together with the selection of superior varieties and the dissemination of seeds, breeding stock and vaccine to farmers. A basic plan for soil classification was carried out. The selection of better vegetable varieties, the establishment of a production system and a properly managed vegetable seed multiplication programme were also implemented.

Establishment of the Agriculture Institute in 1957

The coordinated activities in research and extension were largely the result of the proposal submitted in 1956 by Dr. Harold Macy, Dean of the Institute of Agriculture, University of Minnesota. An Agricultural Extension Act was inaugurated and became effective in February, 1957. Accordingly, the Institute of Agriculture was founded, combining a total of 29 organisations under one agency. The Institute undertook the massive task of rehabilitating, reorganising and reconstructing badly damaged, destroyed or non-existent facilities. With generous support from the U.S. International Cooperation Administration (ICA) and the Korean government, funds were made available for facilities and various items needed for the research, extension and training programmes.

After establishing the Institute, rapid progress was made in many fields of research with emphasis on developing superior varieties of food grain, improved cultural practices, plant nutrition, animal breeding, forage production and cash crops (vegetables, sericulture and fruits). Several major accomplishments were the production of hybrid corn, virus-free seed potatoes, a vegetable seed industry, the development of new soybean varieties, experiments in land reclamation, the manufacture of veterinary biologicals, and many other agricultural advancements.

Establishment of the Office of Rural Development in 1962

The Rural Development Act was enacted to establish a more efficient system of rural guidance and to assist in obtaining expanded and intensified rural programmes necessary for implementing the reconstruction of the nation's economic independence. The Office of Rural Development was founded in 1962. The Office succeeded the former Institute of Agriculture and was assigned the functions, authority and responsibility of developing Korean agriculture through scientific studies. The slightly new direction was based principally on the success of previous work. All available funds, facilities and scientists are used to help the rural farmer raise his standard of living and advance the Government's Rural Modernisation Programme.

The balance of this paper will describe in some detail the structure and functions of the Office of Rural Development and, specifically, the staff and research facilities now available, implementation of programmes, plans for the future and some notable past accomplishments.

IMPLEMENTATION OF RESEARCH PROGRAMMES

Principles of Operation

To assist in carrying out the research programme properly, an Agricultural Research and Guidance Committee was organised and has functioned since 1957. The Committee's main functions are to review and analyse each project, promote research programmes where necessary and ensure as far as possible that all resources are used to the best advantage. The Committee consists of faculty members from the Agricultural Colleges and Universities and most of the senior staff from the Office of Rural Development. The Committee, upon review, recommends projects to the Office of Rural Development for implementation.

Funds

The funds needed for various research activities of the ORD are provided by the Central Government. The Office subsidises funds for regional research pro-

grammes at the Provincial Offices of Rural Development (PORD). The ORD also operates a system of research grants to the Agricultural Colleges, mainly for workers in university departments, and in other research organisations. These grants provide short-term assistance for projects which are of interest to the development of the agricultural sciences.

RESEARCH AT THE AGRICULTURAL COLLEGES AND UNIVERSITIES

There are now ten state supported agricultural colleges and several private university departments conducting research in agriculture. These institutes are administratively controlled by the Ministry of Education (while ORD is under the Ministry of Agriculture and Forestry) and policies are directed primarily to the undergraduate training level with relatively undersupported postgraduate training. Also, fewer research opportunities are given to the faculty staff at the agricultural colleges and universities.

The Office of Rural Development, under these circumstances, is strengthening the system of coordinated operations between the Office of Rural Development and the agricultural colleges. Under this system of mutual cooperation, 62 selected faculty members from agricultural colleges are members of the Agricultural Research and Guidance Committee. Twenty-eight members of this committee have actively participated in joint research projects at the ORD Research Station.

ORD also provides financial grants to selected colleges to support specified agricultural research projects. This close cooperation and financial support has produced a number of remarkable research accomplishments. Two in particular are worthy of mention: (1) a detailed survey covering 123,000 ha. of potential grassland was completed, and (2) the new and improved rice variety IR-667 was a result of this joint cooperation. Varietal improvement of other foods are under study on a continuing basis.

PRESENT ORGANISATIONAL STRUCTURE OF ORD

As shown in the organisation chart in the Appendix there are two bureaus, namely the Research Bureau and Guidance Bureau, and ten subordinate research stations at the national level, under the jurisdiction of the Office of Rural Development. There are also two national research institutes under the Ministry of Agriculture and Forestry which are cooperating closely with the research stations listed. These are the Institute of Agricultural Engineering and Utilisation and the Institute of Agricultural Economics.

In each province there is a Provincial Office of Rural Development (PORD) and under the PORD there are two Divisions, namely a Research Division and a Guidance Division. In addition, there are seed farms, a Veterinary Diagnostic Laboratory and a Sericulture Experiment Station. There are also 172 city or county guidance offices and 618 guidance branch offices throughout the country.

FUNCTIONS

Research Bureau

The planning, coordination, and evaluation of all research programmes and activities conducted at the various research stations, under the Office of Rural Development and the Provincial Office of Rural Development are handled by this bureau. These responsibilities are administered by the Director of the Research

Bureau who is directly responsible to the Administrator of the Office of Rural Development. The Research Bureau is functionally subdivided into three divisions for carrying out its responsibilities. These are: a Research Coordination Division, a Research Management Division and a Research Publications Division. These divisions are concerned with research administration in the planning, coordination and evaluation of all research programmes both current and contemplated, the appropriation and allocation of research funds to the various research agencies, operation and management of the library, publication of all research data available, and the exchange and procurement of reference publications and research equipment. Other important activities are coordination and adjustment of research projects between national and provincial research agencies including the multiplication of seed, seedlings and silkworm eggs, and veterinary vaccine production.

PERSONNEL

The ORD staff has increased steadily since the inauguration of the Central Agricultural Experiment Station in 1946. The following table reflects this growth. The guidance workers are included, due to the important role they occupy as the extension arm of ORD.

Year	Administration	Research	Guidance (Extension)	Total
1954	11	95	—	106
1950	38	195	—	233
1957	77	278	417	765
1962	85	539	3,173	3,797
1970	230	856	6,587	7,673

MAJOR RESEARCH FACILITIES

The Office of Rural Development is fortunate in having ten main stations, two branch stations and nine provincial stations that are reasonably well equipped for basic and/or practical research. The Korean government is giving good support to the Rural Modernisation Programme. However, budgetary limitation, with all its ramifications, makes it difficult for ORD to carry out adequately its assigned responsibilities to its full capabilities. Major research facilities are adequate in number and distribution but some are in need of numerous items of equipment, machinery and more supplies. Staff salaries are inadequate to attract and keep the more qualified scientists, technicians, and rural guidance staff. Personnel loss due to better paying jobs in industry, private enterprise and for other reasons is a continuous disturbing problem. In addition to higher salaries, more opportunities for professional improvement (locally and abroad) of research and rural guidance staff is needed and will help to improve the status of these posts and retain staff. ORD has been fortunate in receiving much outside assistance from the USAID, FAO, and other sources. Without this help the present facilities and professional level of staff would be much less adequate. The following pages will outline briefly the research functions of the main and branch stations, their areas of research, as well as several of their notable recent contributions to the rural modernisation programme in Korea.

Institute of Plant Environment

This station conducts research in the areas of (1) chemical, physical and physiological properties of soils, (2) diagnosis and studies of plant nutritional problems, (3) development of new fertiliser mixtures and soil fertility improvement, and (4) development of improved pesticides based on investigations of the physiology and ecology of plant diseases and insect pests. A major undertaking during the past five years, with generous help from an FAO/UNDP project, was the survey and classification of a large portion of the soils of Korea. Breeding of high producing mushrooms and improvement of cultural practices is another top priority research activity.

Commendable results of intensive work by this Station include: (1) a reconnaissance soil survey of the 9.8 million hectares of Korea's land area and a detailed soil survey of 925,000 hectares of cropland, (2) intensive studies on rice breeding to identify varieties resistant to the 19 strains of blast *(Pyricularia oryzae)*, resulting in the selection of resistant varieties and improved chemical control of this fungus disease, (3) soil fertility studies resulting in increased rice yields using wollastonite in conjunction with nitrogen fertiliser, and (4) a new high yielding mushroom strain '304' which was developed and widely distributed throughout the country. This strain has increased yields by 35%.

Crop Experiment Station

This station occupies 40 hectares of land, has 12 greenhouses and a modern phytotron and is capable of conducting basic research in small grain crops throughout the year. Major emphases are on: (1) breeding superior varieties of rice, wheat, corn, sorghum and soybean, (2) the development of industrial and export crops, and (3) improved cultivation techniques, more efficient cropping systems and intensive land utilisation.

A recent important research contribution was the development of a new rice variety IR-667 in cooperation with the International Rice Research Institute in the Philippines and the College of Agriculture of Seoul National University. This short-stem, blast-resistant variety responds well to heavy fertiliser applications and has demonstrated the ability to increase yields over local varieties by 32%. Three new wheat varieties have been developed through 15 years of intensive breeding work. These varieties show 6 to 32% increase in production over standard local varieties. A new soybean variety, 'Suke No. 36', developed at this station, has shown higher yield over standard varieties and a widespread seed distribution programme is now underway. Improved cultural methods for sweet-potatoes are consistently resulting in increased yields of over 8%.

An international wheat rust nursery, containing 400 wheat varieties from throughout the world, was established in 1970.

Two regional stations, operating in strategic crop production areas, are important institutions working in conjunction with and under close supervision of the director of the station. These are the Honam Crop Experiment Station located in south-west central Korea and the Youngnam Crop Experiment Station established in the important crop area in the south-east central area of Korea. These stations conduct basic and practical research in the same areas as the main crop station. Priority is given to breeding rice and other grains for high productivity, disease resistance and shortened growing season. Attention is also given to solving certain cultivation practices, cropping patterns, pest control, land utilisation, weed control and other problems peculiar to the regions where these stations are located.

Horticulture Experiment Station

All resources of this station are devoted to: (1) improving or breeding new disease-resistant, high producing and better quality varieties of fruit, vegetables and flowers, (2) processing horticulture crops for domestic use and export, and (3) the study of improved cultural practices, labour-saving methods, pest control and intensive crop production techniques.

The Horticulture Station has a record of a wide range of research results which have increased farm income and overall economic development of the rural sector. Breeding and selection experiments have produced outstanding new vegetable varieties such as onion, cabbage and radish, the selection of three new high-producing varieties of hot peppers and a new sweetpear variety, the selection of two tomato varieties for commercial planting and processing, and the selection and breeding of ornamentals and flowers as commercial cash crops. Experimental work in processing has resulted in a wide range of canned, frozen or bottled fruit and vegetable products.

Sericulture Experiment Station

Silk production is an important foreign exchange earning item with great potential for expansion. Research conducted at this station involves all facets of silk production, including: (1) breeding for superior high producing cocoons, (2) selecting high producing mulberry varieties, (3) improved cultural methods, and (4) studies on improved silk processing methods to ensure a higher quality product.

Successful research results include: (1) development of a new silk-worm strain which is capable of increasing silk by 20% over the standard strain, (2) a more efficient cocoon rearing system which is resulting in an increased yield in excess of 4%, (3) more effective insect control in mulberry plantings, resulting in an average increase in yield of leaves by 14%, and (4) intensive studies in more careful and efficient handling of cocoons during the cooking process which promise to produce higher quality silk.

Livestock Experiment Station

Due primarily to the limited land resources of Korea, livestock and poultry production have received less attention than grains and other food crops. The Government is convinced that by maximum utilisation of low potential soils for forage production and by improved breeding of cattle, hogs and poultry it will be possible to greatly increase the amount and quality of animal protein foods.

The ORD Livestock Station staff are conducting research on: (1) the selection, breeding and cultivation of superior types of forage crops, (2) nutritional and management practices, (3) upgrading livestock and poultry by selection and crossbreeding, and (4) the processing and expanded utilisation of poultry and livestock products.

Research results to date in several areas have been quite successful. Crossing of Korean native cattle with imported English beef breeds is resulting in an increase of body weight, from the F_1 offspring, of 13% over the native cattle at 24 months of age. Studies on early weaning, improved feeding, and other good animal husbandry practices have demonstrated that hog production can play an important role in providing additional food and cash income for Korean farmers. Alfalfa planting trials have proven that this highly nutritious forage crop can be economically grown

under Korean conditions when proper cultural practices are followed. Experiments on the selection of superior native grasses and crosses between these and imported species are giving encouraging results in the development of long season grazing and hay crops.

Veterinary Research Laboratory

In line with the expanding livestock and poultry enterprises, ORD is giving priority attention to disease prevention and control. This well equipped facility is directing its efforts to: (1) research on ways and means of preventing and/or controlling livestock epidemics or serious outbreaks of disease, (2) the manufacture of veterinary biologicals, and (3) diagnostic services to government and private veterinary practitioners.

The use of the modern fluorescent antibody and spectrographic electron-microscopic technique and use of other sophisticated equipment is proving of great value in accurately diagnosing diseases and developing more effective biologicals. Provincial veterinary specialists receive regular training at this laboratory. They in turn conduct livestock disease surveys for the laboratory and utilise the diagnostic services of its staff. This facility also has the only completely equipped and staffed poultry research laboratory in Korea.

The Institute of Agricultural Engineering and Utilisation

The Institute is located at the main ORD compound and in April 1970 moved into a new modern building. This facility is considerably handicapped in providing maximum service due to insufficient equipment and machinery. Areas of research cover the entire range of farm machinery for rice and other food crops. Ways and means for the effective utilisation of ground water and other sources of water pertaining to farm operations are receiving priority attention. Mechanical and chemical milling of rice, barley and other grains is under study. Improved techniques and methods of processing and preserving farm products are other research responsibilities.

This institute has a long record of providing practical services and improved items of machinery and equipment for the rural populace. Staff provide teaching services and laboratory facilities for the 4-H Club farm machinery classes which are conducted throughout the year. A power-propelled potato harvester designed at this institute resulted in a harvesting performance 2.7 times faster than the hand method. Successful research was conducted to condense and preserve a wide variety of fruit juices for local consumption and export. A mole drainage driller perfected by agricultural engineers, to be used in the desalinisation of reclaimed tide land areas, reduces the cost of drilling by 50% and the time saved over the winch type drill by 200%. More efficient grain drying equipment, improved plows and other farm equipment, soil and water conservation methods, and improved irrigation systems and methods are other contributions of this facility.

Alpine Experiment Station

This station is located in the mountainous north-east province of Korea. Research is conducted on agriculture and livestock problems peculiar to this hilly region. These include: (1) breeding of disease resistant, high yielding potato varieties, (2) breeding new vegetable varieties and improvement of cultivation practices, (3) selection of superior rice and corn varieties for high elevation, (4) cattle and sheep development and (5) selection of forage crops for higher elevations.

Cattle feeding trials demonstrated the advantage of hybrid animals and proved that good feeding practices were economically feasible. These cattle had a 25% higher body weight and 27% higher dressing percentage which resulted in a 64% increase in gross profit.

Hybrid corn trials resulted in widespread dissemination of improved seed, higher yields and increased hectarage. Experiments with alfalfa and imported grasses are showing promise that with proper care forage crops can become widespread in use in this area. Successful potato experiments include germination control of seed potatoes and the development of varieties resistant to mosaic and other diseases.

Cheju Experiment Station

Located on the Southern Island Province, this Station handles agriculture and livestock problems of importance to this island. The mild south temperate climate and extremely porous volcanic soils of this province offer a challenge to research workers. Areas of research include: (1) improvement and expansion of a potentially large cattle population, (2) forage crop selection, importation and improvement, (3) improvement of vegetables and fruits (some of which are sub-tropical varieties).

Experiments on crossbreeding native cattle with English breeds, and fattening trials using the resulting F_1 offspring, have been uniformly successful. The results showed a 40–60% higher gross income from these experiments. Artificial insemination services from Santa Gertrudis bulls, provided to cattle owners, have been widely accepted and high quality beef is a regular export commodity to markets on the mainland. Alfalfa, brome, Harding, Bahia, Dallis, red clover, white clover and other high quality forage crops are being grown successfully for forage, seed production, and demonstration purposes. Studies on improved cultural practices of vegetables are of importance to Cheju. An experiment on controlled open field cultivation of tomatoes proved that the growing season of this crop and other vegetables can be extended by several months. Vinyl-house production of vegetables and flowers also is receiving attention as a possible means of producing year-round high income crops.

Institute of Agricultural Economics

The research responsibilities of this institute are: (1) to conduct studies and make recommendations on the improvement of farm management and resources, (2) to make economic analyses of special farm income projects, (3) to conduct studies on improving the marketing of agricultural products, and (4) to survey the feasibility of proposed regional agriculture projects.

Recently completed surveys of considerable importance include: (1) an exhaustive analysis of mushroom production in Korea, (2) a detailed study on the economically optimum sizes and structures for Korean cattle and dairy farms, and (3) a hog marketing survey covering the four hog markets in the Seoul area.

PORD Stations

Each of the nine Provincial Office of Rural Development (PORD) Directors has under his supervision and control a Research/Experiment Station. These stations vary considerably in size. Some are well equipped and most are staffed by capable technicians. Others lack needed physical facilities. Financial support for buildings, land, equipment, and supplies comes from the provincial government.

Therefore, the size, scope of operations, and resultant work output is influenced considerably by the amount of budgetary support. Salaries of station personnel are paid from the national budget. Personnel changes or turnover of staff are frequent due to the reasons previously mentioned.

The PORD stations are extensions of the main ORD research stations and do not conduct basic research. Their main functions are: (1) to conduct seed and plant adaptation trials and seed and plant multiplication, (2) to conduct practical sericulture research involving all phases of sericulture, (3) to carry out improved livestock breeding trials, provide artificial insemination services, forage crop experiments and livestock multiplication, and (4) through the veterinary, furnish disease diagnostic services to farmers, conduct surveys involving outbreaks of diseases and provide sanitary services to livestock owners.

These stations have a long history of successful operation and are an important means of 'proving' research results at the farmer level. Provincial trials of the new rice variety IR-667 were successfully completed and the stations are now multiplying this variety for future distribution. Hybrid corn, improved soybean, sorghum, and several forage crop varieties were proven and released to farmers. Hundreds of fertiliser and pesticide trials are conducted annually. As resources permit, purebred cattle, hogs and poultry breeding stock are sold to the farmers for upgrading local breeds or to produce purebred offspring. Staff training and farmers' field days for demonstration purposes are other important functions of these installations.

DISSEMINATION OF RESEARCH RESULTS

In conclusion, a short statement on the role of the Rural Guidance Service in the diffusion process is in order.

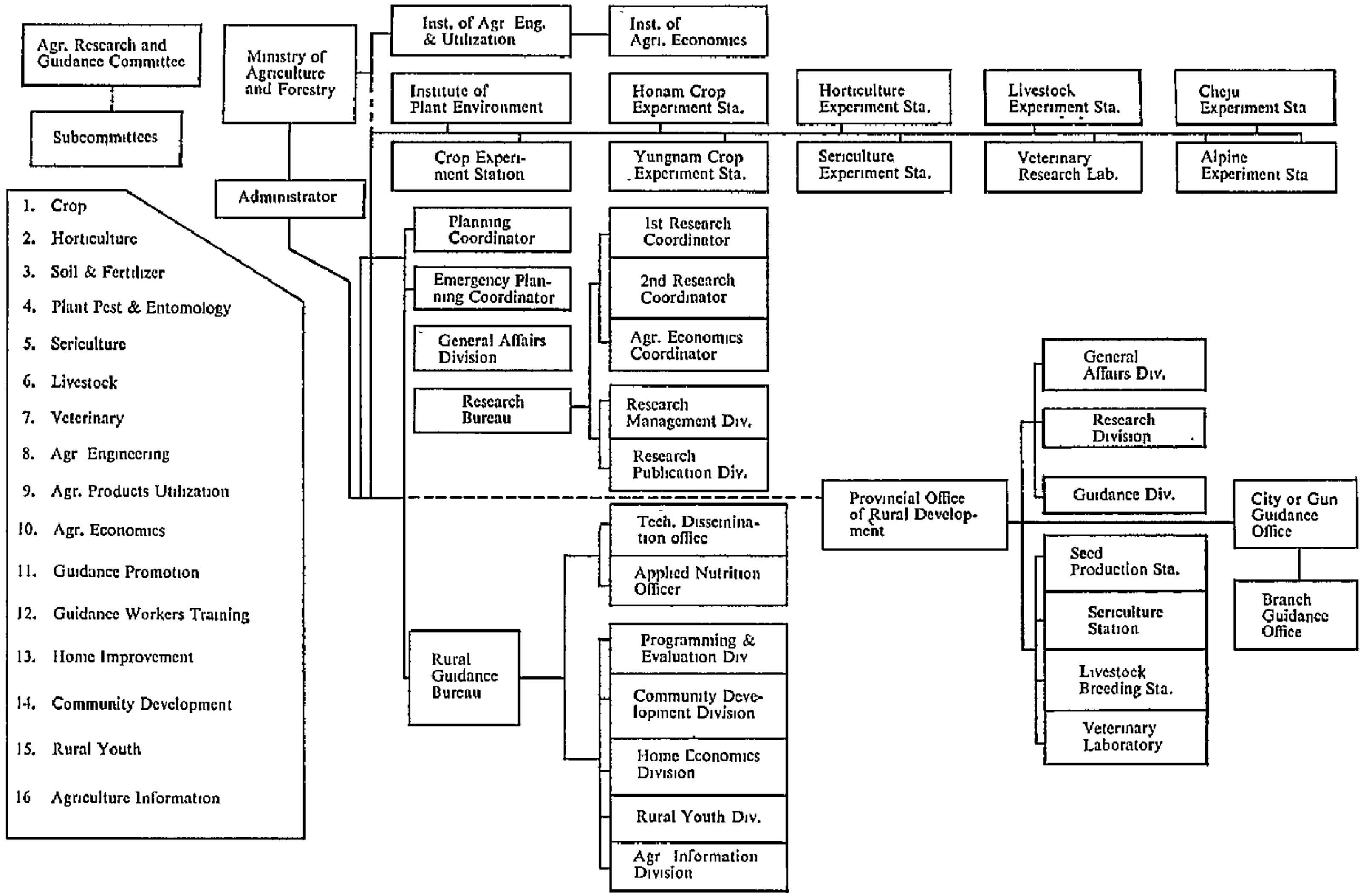
Research findings, demonstration results, development of improved crop varieties, fertiliser and pesticide trials, etc. are of very little value to the farmer if the needed information is not made available to him on a timely and understandable basis.

The extension service in Korea has been a most important influence in the diffusion of agriculture knowledge to rural people. The overall objective of the extension service, as it was established in 1957, is to increase the productivity of farms and farm income through educational and action programmes. In 1962 various functions including community development, rural youth and extension were combined for better efficiency and ease of administration into a Rural Guidance Bureau. This bureau contains five divisions: Programming and Evaluation, Agriculture Information, Rural Youth, Home Economics and Community Development.

Educational methods used by staff of the Guidance Bureau to carry information to the farmers cover the full range of facilities available. Publications (leaflets, bulletins, newspapers), posters, charts, radio broadcasts, films, slides and field audio-visual mobile units are all part of the work of the Information Center in Suwon.

More than six thousand Province Rural Guidance Workers, under the direction of PORD Director's Guidance Division, use every means at their disposal to transmit research results to farmers. Demonstrations are the most important guidance teaching devices. Other methods such as farmers' meetings, farm visits, office contacts, publications, etc. play a major role in the dissemination of information. Village Development Councils, working under the guidance and supervision of the guidance agent, help organise cooperative groups and plan educational programmes.

APPENDIX



Agr. Research and Guidance Committee
Subcommittees
Ministry of Agriculture and Forestry
Administrator
1. Crop
2. Horticulture
3. Soil & Fertilizer
4. Plant Pest & Entomology
5. Sericulture
6. Livestock
7. Veterinary
8. Agr Engineering
9. Agr. Products Utilization
10. Agr. Economics
11. Guidance Promotion
12. Guidance Workers Training
13. Home Improvement
14. Community Development
15. Rural Youth
16 Agriculture Information
Inst. of Agr Eng. & Utilization
Inst. of Agri. Economics
Institute of Plant Environment
Honam Crop Experiment Sta.
Horticulture Experiment Sta.
Livestock Experiment Sta.
Cheju Experiment Sta
Crop Experiment Station
Yungnam Crop Experiment Sta.
Sericulture Experiment Sta.
Veterinary Research Lab.
Alpine Experiment Sta
Planning Coordinator
Emergency Planning Coordinator
General Affairs Division
Research Bureau
1st Research Coordinator
2nd Research Coordinator
Agr. Economics Coordinator
Research Management Div.
Research Publication Div.
Rural Guidance Bureau
Tech. Dissemination office
Applied Nutrition Officer
Programming & Evaluation Div
Community Development Division
Home Economics Division
Rural Youth Div.
Agr Information Division
Provincial Office of Rural Development
General Affairs Div.
Research Division
Guidance Div.
Seed Production Sta.
Sericulture Station
Livestock Breeding Sta.
Veterinary Laboratory
City or Gun Guidance Office
Branch Guidance Office

The Malaysian Agricultural Research and Development Institute

ANI BIN AROPE
Deputy Director, MARDI, Kuala Lumpur, Malaysia.

Agricultural research is not new to Malaysia. However, its importance in the economic development of the country has not had much appreciation and backing from the general public until in recent years. This is understandable as the country's economy has been built mainly on rubber and tin. These have provided, and are still providing, nearly all the foreign exchange earnings to maintain national economic stability.

Rubber is the lifeblood of Malaysia. In 1969 nearly 1.25 million tons of rubber were exported, earning almost M$1.9 billion in foreign exchange. These figures represent approximately 60% of the total export income and almost one-third of the total gross national product. Rubber is planted on more than five million acres, representing 60% of the available agricultural land; it provides employment for approximately two-thirds of the country's working population who depend on agriculture for their livelihood.

Rubber research on all aspects of production, processing and marketing plays an important role in the improvement of rubber in the country. The continued strong position of natural rubber in world markets in competition with rubber substitutes or synthetics has depended largely on the success of research to increase productivity and to improve the quality of Malaysia's rubber.

Malaysia produces other agricultural products for export apart from rubber. These include oil palm, coconut oil, copra, canned pineapple and tapioca flour. The country also produces large quantities of rice, fruits and vegetables for domestic consumption.

The imports of agricultural products represent a substantial portion of the total imports into Malaysia. In a normal year approximately 25% of the total imports are foodstuffs, including rice, cereals, fruits, vegetables and dairy products. The cost of these approximates M$600 million a year.

With the marginal decline in tin and rubber prices on world markets, Malaysia is seeking other sources of foreign exchange earnings and means to reduce foreign exchange spendings. Realisation of the importance of agriculture as a source of greater foreign exchange earnings and savings is reflected in the national

development programmes pursued after the country attained independence. About 13% of the national budget is now spent for agricultural development.

MALAYSIA'S AGRICULTURAL RESEARCH BASE

Until recently research in agricultural crops other than rubber and pineapple was the responsibility of the Division of Agriculture. The Veterinary Division conducted research in animal production and on animal diseases. The Fisheries Division conducted research on both fresh water and marine fisheries. Research on food technology was initiated in 1966 in the Division of Food Technology of the Ministry of Agriculture and Lands.

Research in rubber is done by the Rubber Research Institute of Malaya which was established in 1925.

The Malayan Pineapple Industry Board, through a cess on the exports of pineapple, supports production and processing research on this crop.

THE EVOLUTION OF MARDI

With the growing recognition that the country must diversify its agricultural based economy, the Government of Malaysia has taken steps to strengthen the national research capability and the coordination of research through establishment of the Malaysian Agricultural Research and Development Institute (MARDI).

Apart from the awareness of the need to increase diversification of the country's agriculture this action reflected the growing appreciation of the need for improved technology in agricultural growth and the increased concern over potential proliferation of separate organisations for research in agriculture, livestock, oil palm production and other areas.

The initial proposal for the establishment of the Malaysian Agricultural Research and Development Institute, as an autonomous body, was made by the Agricultural Diversification Sub-committee of the National Development Planning Committee. This recommendation to the Economic Committee of the Cabinet on December 23, 1967 proposed that a number of existing Government research and extension agencies should coalesce to form the nucleus of the new Institute.

The three compelling reasons put forward for the establishment of MARDI were:

(1) For an autonomous research organisation to provide the administrative flexibility required for creative, productive research and high staff morale.

(2) For the successful attraction and retention of competent and well qualified research workers through the offering of significantly higher salaries and better, albeit-stricter, conditions of service than those provided by the Government within the present strictures of the civil service.

(3) For a statutory body to facilitate continuity of research including long range planning and budgetting.

The Economic Committee of the Cabinet at its meeting on January 24, 1968 approved in principle the recommendation for the establishment of MARDI and set up a Working Committee which was directed to develop plans for the scope, functions and organisational structure for the Institute. The Working Committee gave intensive attention to this task and the recommendations and draft bill for the establishment of MARDI were prepared in September — October 1968.

The MARDI Act was passed by Parliament on February 14, 1969.

SOME SPECIAL PROVISIONS OF THE MARDI ACT

The Act establishes the Malaysian Agricultural Research and Development Institute as an autonomous body with linkages to Government through the Ministry of Agriculture and Cooperatives (now the Ministry of Agriculture and Lands).

The guidance for administrative management of the Institute falls under the Governing Board, with up to 11 members from Government and the private sector. The Board has the following functions:

(a) Subject to the direction of the Minister, to determine the policies in the administration of the Institute.

(b) To determine the procedure with respect to appointments, promotions and termination of appointments of employees and servants of the Institute, exclusive of the Director and Deputy Director.

(c) With the concurrence of the Minister, to approve the budgets or estimates of expenditure with respect to the administration and operation of the Institute.

(d) To issue administrative rules relating to the day-to-day administration of the Institute.

The Governing Board is also empowered, with the approval of the Minister of Agriculture and Lands, and with respect of (a) and (b) subject to concurrence of the Minister of Finance, to make rules on the following matters:

(a) The determination of salary scales and terms and conditions of employment of the officers and servants of the Institute, including the provisions of loans to such officers and servants.

(b) The establishment and management of a contributory provident fund for the officers and servants of the Institute or for payment of pensions, allowances or gratuities to the said officers and servants on retirement or otherwise ceasing to hold office.

(c) The principles and procedures with respect to appointments, promotions and termination of appointments in the Institute, exclusive of the Director and Deputy Directors.

(d) The principles and procedures for the evaluation of capability and performance of the professional staff of the Institute.

(e) Any other matter which may be prescribed under this Act.

The technical guidance for MARDI is furnished by the 11 member Scientific Council which has the following duties:

(a) To advise on the formulation of and review the research programmes of the Institute.

(b) To define priorities for the research and development programmes of the Institute to ensure maximum quality and effectiveness.

(c) To maintain liaison with external organisations, both in the public and private sectors, and to maintain contact with agricultural research needs.

(d) Subject to any procedure prescribed by the Board, to determine and allocate grants in aid for research to be conducted by other organisations or agencies.

(e) Subject to any procedure prescribed by the Board, to select recipients of scholarship and issue awards or travel grants to be financed by the Institute.

(f) To furnish guidance in the development of research facilities including the selection of locations and laboratory facilities and supervision of major items of specialised equipment.

(g) To advise on the procedures for the evaluation of capability and performance of the professional staff appointed under this Act, including promotions on professional merit.

(h) To advise on the library, documentation services and publications of the Institute.

The Director of the Institute and two Deputy Directors are appointed by the Yang Di-Pertuan Agong (The King) from among persons nominated by the Minister after consultation with the Scientific Council. Their appointments are made for such periods and on such terms and conditions as may be agreed upon and specified in their respective letters of appointment.

MARDI has broad geographical responsibility, including both West and East Malaysia, and its specific functions are:

(a) To conduct scientific, technical, economic and sociological research in Malaysia with respect to the production, utilisation and processing of all crops (except rubber), livestock and fresh water fisheries.

(b) To serve as a centre for the collection and dissemination of information and advice on scientific, technical and economic matters concerning the agricultural industry, including the publication of reports, periodicals and papers relating thereto.

(c) To act as a centre for specialist extension service in the agricultural industry.

(d) To advise on the training of workers for scientific and technical research and extension.

(e) To provide grants in aid for the purpose of pure and applied scientific, technical and economic research concerning agricultural industry.

(f) To maintain liaison with other organisations, both public and private, indigenous and foreign, which are engaged in scientific, technical, economic and sociological research concerning the agricultural industry.

IMPLEMENTATION

The inauguration of MARDI took place on October 28, 1969. The Deputy Prime Minister, the Hon'ble Tun Abdul Razak bin Hussain, gave the principal

address and announced the membership of the Governing Board and the Scientific Council as well as the Director of the Institute. Dr. A. H. Moseman of the Agricultural Development Council is serving as the Director of MARDI at the request of the Prime Minister during the initial years. He has been involved in the development of MARDI beginning with the review of agricultural research in Malaysia in April — May 1968, conducted at the request of the Deputy Prime Minister. He subsequently served as consultant to the Working Committee in planning the scope, functions and organisational structure of MARDI and in the drafting of the MARDI Bill.

Since the inauguration of MARDI, attention has been given to the development of the research organisation, to the procedures and policies for staffing, including staff development, and to the consolidation of research resources.

It was intended, from the initial proposal for establishment of MARDI, that the Institute be based upon existing research programmes and resources. This has required serious consideration of the laboratories, field stations, equipment, and personnel to be transferred from the various Divisions of the Ministry into MARDI. Since some of these stations, staff and other resources were involved in multiple functions this sorting out has proved to be somewhat difficult.

The research of MARDI is to be established in six Divisions, each with a number of branches concerned with specific commodities or problem areas, as follows:

1. Crop Improvement Research Division
   (a) Oil Palm Research Branch
   (b) Rice Research Branch
   (c) Feed and Fodder Crops Research Branch
   (d) Vegetable Crops Research Branch
   (e) Tree Fruit and Beverage Crop Research Branch
   (f) Cocoa and Coconut Research Branch
   (g) Pineapple Research Branch
   (h) Sugercane Research Branch
   (i) Plant Introduction Branch
2. Animal Improvement Research Division
   (a) Beef Cattle Research Branch
   (b) Dairy Research Branch
   (c) Swine Research Branch
   (d) Poultry Research Branch
   (e) Fresh Water Fisheries Research Branch
3. Soils, Water and Engineering Research Division
   (a) Soil Classification Branch
   (b) Soil Fertility and Management Research Branch
   (c) Peat Soils Research Branch
   (d) Water Management Research Branch

(e) Agricultural Engineering Research Branch

4. Crop Protection Research Division
   (a) Insect Pest and Disease Control Research Branch
   (b) Pesticide Materials Research Branch
   (c) Rodent and Bird Control Research Branch
   (d) Weed Control Research Branch

5. Crop Utilisation and Food Technology Research Division
   (a) Processing and Utilisation Research Branch
   (b) Food Technology Research Branch
   (c) Crop Quality Analysis Services

6. Economics and Statistics Research Division
   (a) Production Economics and Farm Management Research Branch
   (b) Marketing Research Branch
   (c) Experimental Design and Statistical Services

Priority attention will be given to research on oil palm, rice improvement, soils and water, livestock production including feed and fodder crops, and to economics and marketing. There is special concern at the present time to improve the position of rural people in Malaysia, particularly the smallholder farmers, and this factor will be kept in mind in planning research to support specific rural development activities.

FACILITIES — WEST MALAYSIA

One limiting factor in the past research in Malaysia has been the inadequacy of the research stations and laboratories. The inclusion of various functions in the Federal Experiment Station at Serdang and at other field stations has tended to restrict the land area suited for the scope of field research required for crop improvement, soils and agronomic investigations.

In planning MARDI's research station development programme for the Second Malaysia Plan, from 1971-1975, priority will be given to (1) setting up a Headquarters Station near Kuala Lumpur, (2) a Southern Regional Station in Johore and (3) a Northern Regional Station near Penang. These will be supplemented by five stations transferred from the Division of Agriculture of the Ministry, to be concerned with special problem areas under different soil and environmental conditions.

Action is in process to acquire a 1200 acre rubber estate near the existing Federal Experiment Station at Serdang, and adjoining the College of Agriculture, to serve as the Headquarters Station. It is intended that approximately 30% of the research staff will be located at this Headquarters Centre covering a broad scope of research.

Steps have been taken to acquire about 3000 acres of state land in a new land development scheme in Johore, about six miles south of Kluang, to serve as a regional station for the southern part of West Malaysia.

Sites are now under study for a station for research on rice and other crops in the northern region, to supplement the facilities at the Headquarters for the Rice Research Branch which is now at Bumbong Lima.

The five stations transferred to MARDI from the Division of Agriculture include:

(1) The Rice Research Station at Parit, Perak
(2) FES Cameron Highlands, Pahang, for research on vegetables
(3) FES Sungai Baging, Pahang, for studies on bris or sandy soils
(4) FES Jerangau, Trengganu, representing the high rainfall conditions of the East Coast area
(5) FES Jalan Kebun, Selangor, for studies on peat soils

It is recognised that several years will be required for the establishment of the new research stations and facilities but in the meantime research will be carried on in the existing research laboratories of the Ministry in Kuala Lumpur, at the present Federal Experiment Station at Serdang, and at the Bumbong Lima Rice Research Station, in addition to the facilities transferred to MARDI. The distribution of the existing and planned research stations for West Malaysia is shown in the *Appendix.*

STAFFING

The basic or nucleus staff for MARDI is to come from the research units of the Ministry of Agriculture and Lands. There are approximately 60 persons in the Ministry who have been involved in research in agriculture, livestock improvement and other fields. It has taken some time to work out procedures for the transfer of these research personnel, particularly to ensure continuity of their pension and provident fund arrangements as they move from Government service to an autonomous body. The actual transfer was on March 1, 1971.

The response to the advertisement for positions in MARDI, in May 1970, was exceptionally good. Research personnel from the Rubber Research Institute of Malaya, the Faculty of Agriculture of the University of Malaya, private industry research organisations and persons in training abroad expressed interest in employment with the Institute.

It is intended that MARDI be established, in so far as possible, with qualified Malaysians occupying the permanent leadership posts. No full time positions are to be filled by non-Malaysians although short term appointments may be offered to non-citizens; certain posts may be filled on a temporary basis by persons available from cooperating technical assistance organisations.

STAFF DEVELOPMENT

The shortage of trained and experienced personnel is a major limiting factor in the establishment of MARDI. An initial goal has been set for the recruitment and training of staff to include 50 Ph.D's, 100 M.Sc's, and 200 with B.Sc. degrees.

It is recognised that the development of human resources must be a national responsibility and cannot be left to uncertain support from external fellowship and technical assistance programmes. Provision has been made in the Second Malaysia Plan for financing of the training in accord with the objectives outlined above. It is probable that the limiting factor in achieving the schedule of training projected will be the lack of qualified persons available for such advanced training. There is strong competition for graduates from the University of Malaya and from the College of Agriculture so the number available to MARDI is yet not certain.

COOPERATION WITH EAST MALAYSIA — SABAH AND SARAWAK

As mentioned earlier, while the Central Government has primary responsibility for agricultural research, the states of Sabah and Sarawak also have some continuing responsibilities for such work. The relationship between MARDI and these states will be developed through cooperative support for selected projects for which the states will supply:

(1) Land, laboratories and other research facilities.
(2) Technicians, labour and similar supporting staff.
(3) A major portion of the operations budget.

MARDI will supply, as mutually agreed upon:

(1) Research personnel.
(2) Specialised research equipment.
(3) Training opportunities.
(4) Some operating budget.

It is expected that the states of East Malaysia will participate in the programmes concerned with rice improvement, oil palm research and other similar broad national programmes. In addition, MARDI would expect to collaborate in certain projects of special interest such as the research on pepper and other specialty crops in Sarawak.

EXTERNAL COOPERATION

There has been substantial continuing cooperation between Malaysian research workers and other national and international organisations over many years.

The Rice Research Branch, now under MARDI, has cooperated with the International Rice Research Institute from the time the IRRI linkages were first established with the different countries of the region.

Malaysia was the first country to recommend and distribute the variety IR-8 (under the name Ria) in 1966. Similarly, the Rice Research Unit has distributed the variety Bahagia, a sister selection of IR-5, made available from the IRRI rice breeding programme.

The Rice Research Branch is continuing the collaboration with the IRRI, not only in testing of breeding lines but also in pathology and other fields.

There has been collaboration in maize and sorghum improvement, initially with the cooperative maize scheme supported by the Rockefeller Foundation in

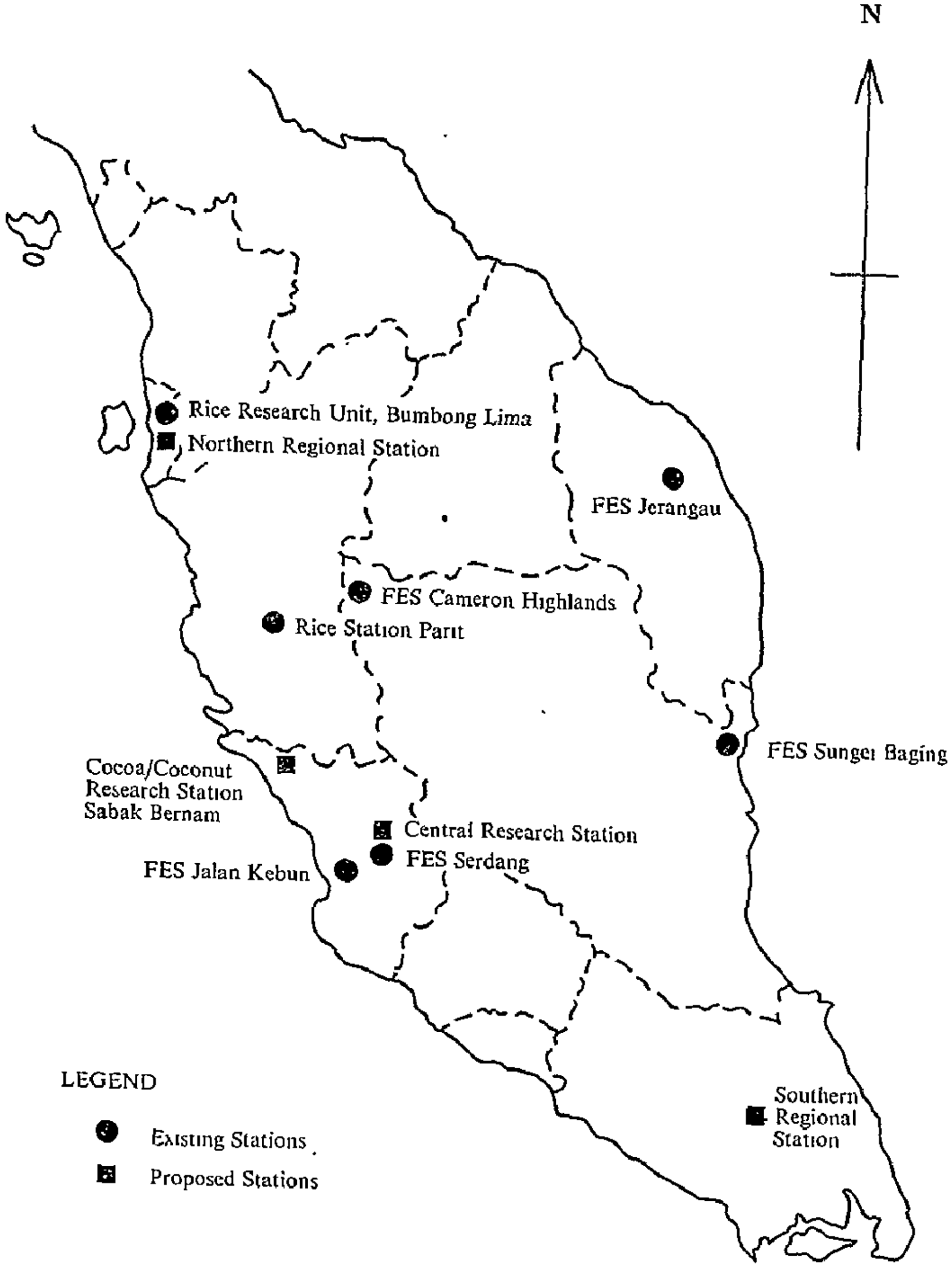
India, and later with the Maize and Sorghum Improvement Centre in Thailand. This collaboration has not been as sustained as the cooperation in rice research, primarily because of the lack of continuity of the research personnel concerned with maize improvement in Malaysia. It is expected that the establishment of MARDI, with the concentration of research workers and teams of scientists in specific problem areas, will improve the continuity and stability of these research programmes.

Agricultural research personnel from Malaysia have participated in a wide range of other cooperative endeavours and international conferences. It is recognised that such interchanges are essential to the national interest.

The establishment of MARDI has been regarded by a number of international and bilateral technical assistance organisations as furnishing an attractive base for cooperative projects in research and technical cooperation. Negotiations are underway with the Government of Australia to furnish cooperative support for research on pastures and fodder crops, essential to the strengthening of livestock production in Malaysia. Support for specialists and for training is being furnished by the FAO/UNDP for research in soils, water management and engineering, and horticulture. The Governments of the United Kingdom, New Zealand, Canada, Belgium, Japan and others have expressed interest in cooperative support for research as the MARDI organisation is established and as problem areas of mutual interest can be identified.

Many countries have offered 'volunteers' to assist with MARDI research projects. These volunteers will be especially helpful in carrying out research projects while Malaysian research workers are released to pursue their advanced training. Special emphasis in recruitment of volunteers has been placed on those with advanced training through the M.Sc. and Ph.D. degrees.

EXISTING AND PROPOSED RESEARCH STATIONS FOR M A R D I



Agricultural Research in Nepal

N. B. BASNYAT

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Nepal, a landlocked country of 141,577 sq. km., is basically an agricultural country and one of its biggest source of wealth is produce from the land. The basic necessities of life — food, clothing and shelter — are supplied by agriculture, along with raw materials for industry. According to the 1967-68 estimates, agriculture accounts for 66% of the gross domestic product. More than 93% of the total labour force of the country is engaged in agriculture, and agricultural products are the major items in the export trade. Of the total export, food grains constitute about 70%.

Soil fertility and productivity of the land is low. In addition, the increasing population is exerting heavy pressure on the limited available cultivated land, giving rise to critical problems of providing gainful employment to the growing labour force in agriculture. Emphasis must be given to agricultural development to transform the tradition-bound and largely monsoon-based subsistence agriculture into a modern and commercial enterprise.

PROGRESS IN THE AGRICULTURAL SECTOR

Agricultural development has been emphasised by the government since the First Plan period. As a result, adaptive research suited to the varied climatic conditions of the country has been conducted in different fields of agriculture. Results of the research are disseminated to the farmers through the agricultural extension programme. In addition, a nation-wide land reform programme has been implemented during the Second Plan Period.

Several departments have been established to conduct adaptive research to improve crop varieties, on livestock, fisheries, etc. for the different climatic conditions of the country, as shown in the Organisation Chart in the *Appendix*. Under these departments there are six agricultural research stations, four agronomy farms, twenty-three horticulture development centres, four livestock development farms, three poultry hatcheries, thirty-four livestock hospitals and dispensaries, three cheese factories, one dairy centre and ten fishery centres located in different parts of the country.

In order to establish a close link between agricultural research and farmers, an agricultural extension programme is being implemented under the supervision of

graduate level Agriculture Development Officers who are posted in 43 out of 75 districts. The organisation structure has been further modified recently to bring about more coordination by establishing six regional offices at the zonal level.

In the field of training during the last four years, more than 800 Junior Technical Assistants have been trained and 1870 farmers have received practical training. An Agriculture College has been established to train higher level agricultural technicians inside the country. In addition, the Agricultural Development Bank, the Land Reform Savings Corporation and the Agricultural Supply Corporation have been established to provide credit, fertilisers, seeds, implements and other inputs to the farmers. A Dairy Development Corporation has also been established to run the dairy enterprise along business lines. A minor Irrigation Department has been established under the Ministry of Agriculture to develop facilities for the Agricultural Development Programme.

A perusal of the progress made so far in the development of agriculture shows that the use of the high yielding inputs like improved seeds, fertiliser and the provision of irrigation facilities are at a very low level. Improved seeds have been used only on 102,640 out of 1,845,000 hectares of cultivated land and the annual use of chemical fertiliser has amounted to only 24,000 metric tonnes. Similarly, irrigation facilities have been provided to 117,500 hectares, which is only 6% of the total cultivated land. Although in the last four years agricultural institutional reforms have been introduced and several agricultural institutions have been established in the agricultural sector, much remains to be done to make them more effective.

AGRICULTURAL RESEARCH

The Department of Agriculture was reorganised in 1966 and a separate Department of Agricultural Education and Research was created. The main objective of this Department is to increase the quality and quantity of cereal and cash crops of major importance through clearly defined research and experimental projects in the principle agricultural areas of Nepal.

The present research on cereal grain production is conducted in a coordinated programme which has been well designed to obtain information under the varied ecological conditions. Ten experimental farms have been established at different locations. The working programme is prepared in consultation with all divisional chiefs before implementation. A Coordinated Research Project is prepared for a full cropping year which outlines the programme for varietal trials, fertility investigations, plant protection measures, irrigation practices, etc. At the end of the cropping season a final summary is presented by the coordinator for final evaluations. This type of research is conducted on the major crops such as rice, wheat and maize. A Coordinator is appointed for each crop.

The varietal testing programme is based on the collection of germplasm found both inside and outside the country. More emphasis is placed on adaptive rather than basic research. Most of the outstanding lines of major crops are introduced from international agencies such as the IRRI, CIMMYT and others. Personnel are trained in these institutions to conduct breeding and selection trials under varied ecological conditions. In addition, proven varieties have been multipled on progressive farmers' plots, certified, bagged, tagged and released for commercial use. Improved varieties of maize have been recommended for the higher altitudes, the valley region and the Terai plains. Kakani yellow (Antigua group 2 × Guatemala), Khumaltar yellow (Antigua 2D × Guatemala) and Rampur yellow (Composite) have undergone further selection and are widely accepted by farmers.

Similarly, different varieties of rice and wheat are tested and further selected to meet farmer's requirements.

Organised fertiliser experiments and soil testing started in Nepal only seven years ago. Fertiliser experiments have been conducted in five agriculture experimental stations, namely Parwanipur, Rapti, Bhairahawn, Biratnagar and Khumal.

The systematic soil survey work in Nepal started in 1964. The survey work was of exploratory to reconnaissance type on cadastral survey maps (1 inch to a mile 1:63,360 topo-sheets). The soils were classified on the basis of mechanical or physical composition, effective depth of the soil profile and drainage conditions. Soil fertility maps of the surveyed areas are produced to show pH, organic matter, nitrogen, phosphorus and potassium content. To date, about 2.7 million hectares of land have been surveyed, covering mostly the Terai plain and a few important valleys in the Churia and Mahabharat hills.

In the Fourth Plan Period (1970–75), the target is to survey twenty-two hill districts, using aerial photographs on the scale 1:35000. In addition, the UNDP S/F project 'Increased use of High Yielding Crop Varieties and Fertilisers' will survey thirteen districts of central Nepal in a four-year period.

The use of chemical fertilisers in Nepal has been very much increased with the introduction of high yielding crop varieties. Fertiliser trials have been limited to government experimental stations. In general, fertiliser use increased yields profitably; however, in some cases, due to the nature and properties of soil, the response is erratic. It is, therefore, realised that specific recommendations on the economic use of fertilisers can be based only on the results obtained from trials conducted on specific soils. In this connection, His Majesty's Government of Nepal and the UNDP S/F project have jointly started fertiliser trials on wheat, on farmers' fields, in six districts of central Nepal. Similar trials on paddy and wheat will also be conducted during the season for a possible period of four years.

In Nepal, most of the pests and diseases of economic importance have been surveyed and identified. Because of the increasing use of high yielding varieties, it has become essential to study the effectiveness of different pesticides and fungicides to control major pests and diseases. Trials have been conducted at the experimental farms and the proven results have been recommended to the farmers.

Varieties with built-in resistance to major diseases have been identified. The international wheat rust nursery and rice blast nurseries have been laid out in different climatic regions of Nepal. Plants showing disease resistance are selected for further studies on agronomic characters. Similar studies are being made on other important crops and some promising lines of potato, resistant to late blight disease, have been released to growers.

Water has become a major limiting factor in some districts of Nepal, especially where surface water is in short supply. In these regions the high yielding varieties have limited scope because of the lack of essential water input. Ground water exploration has been completed in some of the districts and there is a possibility of utilising ground water. In these regions better water and land management is essential. Not much work has been done on this subject and a water utilisation project was established recently under the Technical Assistance programme of the UNDP/FAO. This project outlines the economic use of water, in reference to the high yielding varieties and the increased use of fertilisers. Trials will be conducted in the tube-well irrigated areas and the cost/economy ratios will be established.

The agricultural research programme is aiming at the diversification of farming. In order to accomplish this the Department of Agricultural Education and Research has outlined projects which will help to establish a planned programme for identification and utilisation of additional crops which are of economic importance.

APPENDIX

ORGANISATION OF THE DEPARTMENT OF AGRICULTURAL EDUCATION AND RESEARCH

Ministry of Food and Agriculture, Nepal

- Department of Agricultural Education and Research
  - Research
    - Agronomy
    - Botany
    - Entomology
    - Plant Pathology
    - Soil Science
    - Ag. Engineering
    - Ag. Station-Parwanipur
    - Ag. Station-Biratnagar
    - Ag. Station-Bhairawa
    - Ag. Station-Rampur
    - Agronomy Farm-Nepalgunj
    - Ag. Farm-Khumaltar
    - Ag. Farm-Janakpur
    - Ag. Farm-Doti
    - Maize Improvement-Kakani
  - Education
    - College of Agriculture
  - Service
    - Agronomy
    - Botany
    - Entomology
    - Plant Pathology
    - Soil Science
    - Ag. Engineering
    - Ag. Station-Parwanipur
    - Ag. Station-Biratnagar
    - Ag. Station-Bhairawa
    - Ag. Station-Rampur
    - Agronomy Farm-Nepalgunj
    - Ag. Farm-Khumaltar
    - Ag. Farm-Janakpur
    - Ag. Farm-Doti
    - Maize Improvement-Kakani
- Other Departments
  - Extension
  - Horticulture
  - Fisheries
  - Animal Husbandry

Agricultural Research In The Philippines

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The Philippines, like other developing countries, has an agricultural-based economy. One-third of the gross national product of the country is derived from agriculture and at least 60% of the labour force is engaged in agricultural pursuits. The Philippines has a population of 37 million people, with an annual growth rate of 3.06%.

The Philippines is in the tropical zone (4^0 40^1 to 21^0 10^1 north latitude). Climatic conditions are suitable for continuous cropping throughout the year. Seasonal fluctuations in temperature are minimal and rainfall (ranging from 75 to 125 in. annually) is distributed in 8-10 months of the year. At least two annual crops are grown a year. With supplemental irrigations during the two to four months of low rainfall, three or more croppings a year are possible so the opportunities for intensifying crop and animal production are very great. The only physical limitation is the frequent occurrence of typhoons from June to November.

The agricultural potential of the Philippines has not been fully exploited and production levels are generally low. However, the success in rice production has demonstrated that through collective effort of the public and private sectors, productivity can be improved and accelerated at a substantial rate to meet the needs of the burgeoning population and to support national economic development.

Agricultural research played a vital role in attaining the needed production efficiency in rice. We are confident that our limited resources for research, if used to maximum advantage, can help provide the necessary answers for the immediate as well as the long-term requirements of the country for sound agricultural and economic development.

ORGANISATION FOR AGRICULTURAL RESEARCH AND DEVELOPMENT

RESOURCES FOR RESEARCH

The organisation for agricultural research in the Philippines is quite loose and has proliferated into individual compartments of responsibility. There is no formal tie-up among the different research agencies.

There are three major organisations engaged in agricultural research, namely, (1) the Department of Agriculture and Natural Resources (DANR), (2) the National Science Development Board (NSDB), and (3) the state and private agricultural colleges and universities. A complete list of research agencies is shown in the *Appendix.*

A number of private firms and corporations are also actively engaged in agricultural research. Prominent among these are the big corporations producing export crops like pineapple, bananas, rubber and coconut, and the fertiliser and agricultural chemical companies. Since their research results are, for the most part, for exclusive company use their activities are not included in this paper.

The DANR belongs to the executive branch of the national government and undertakes applied research on the production, utilisation and economics of crops, livestock, fishery and forestry resources through its agencies: (1) Bureau of Plant Industry, (2) Bureau of Animal Industry, (3) Bureau of Soils, (4) Philippine Fisheries Commission, (5) Bureau of Agricultural Economics, (6) Bureau of Forestry, (7) Reforestation Administration, (8) Parks and Wildlife Office, (9) Philippine Sugar Institute, (10) Philippine Tobacco Administration, and (11) Abaca and other Fibres Development Board. The DANR has many outlying research stations and farms in the country.

The NSDB, created by law as a national coordinating body for research and to furnish grants-in-aid, maintains its own research arms, namely, (1) the National Institute of Science and Technology, under which are the Food and Nutrition Research Council and the Agricultural Research Centre, (2) the Philippine Atomic Energy Commission, which has an agricultural section, (3) the Philippine Coconut Research Institute and (4) Forest Products Industry Development Commission. The National Institute of Science and Technology conducts applied and basic research on human nutrition, plant and animal product utilisation, and some aspects of crop production. The agricultural section of the Philippine Atomic Energy Commission engages in research on the use of radioisotopes in entomology, plant nutrition and varietal improvement of crops.

The various agricultural institutions for higher learning represent a major segment of the total resources for research. Ten major colleges and universities (public and private) undertake basic and applied research on crop and animal production — including fishery, economics, sociology, food technology and human nutrition. Research is integrated with undergraduate and graduate education.

The national agricultural extension service, which is the responsibility of the Agricultural Productivity Commission, is under the Office of the President of the Philippines and is not attached to any major research organisation.

Attempts have been made to effect coordination of research activities among the different organisations but the only semblance of coordination is what is already in the existing built-in systems provided by law.

A national body, the National Economic Council of the Philippines, is charged with the function of formulating national economic policies and programmes of development with the sanction of Congress and the President of the Republic. The different research agencies in the executive branch of the government and other sectors are expected to take the initiative in translating these broad policies into specific research programmes.

The National Science Development Board was established in 1958, specifically to serve as a central coordinating body for all research activities in the country. But since the agency has no defined authority or any form of administrative control over the activities of the various research agencies outside it, the agency has not been able to pursue vigorously its responsibility as a coordinating body and has served mainly as a grants-in-aid giving agency.

The Research Council of the Philippines, which is composed of key research scientists and personages representing the whole scientific community of the country, serves as an advisory body to the Office of the President on matters pertaining to national research policies.

RESOURCES FOR RESEARCH

Funds

In 1966, a total of 44.8 million pesos (U.S.$11.2 million) was spent on agricultural and industrial research and development in the Philippines. The amount represented only 0.22% of the GNP, which is considered low to produce the needed 'critical-mass' effect for sizeable benefits and impact. Of the 44.8 million pesos spent for research, 42.7% was spent by the national government, 24.2% by the private industrial sector, 13.4% by institutions of higher learning and 15.2% by non-profit organisations and foundations. Of the total expenditures for research and development, 50.2% was spent for agricultural research.

The fiscal resources of the national government for research and development have increased considerably lately by virtue of a law which established the *Special Science Fund.* Funds were generated from fees paid for the registration of motor vehicles and proceeds from the sale of documentary stamps, providing about 38 to 44 million pesos (U.S.$6-7 million) a year for research. The fund is administered partly by the National Science Development Board to support applied research and partly by the Research Council of the Philippines which assists in funding basic research. The Special Science Fund is given out as grants-in-aid to any research agency which may wish to apply for financial assistance.

The DANR, aside from its regular appropriations for research for the various bureaus under its control, gets an additional sum of 10 million pesos a year which it uses to finance production-oriented and impact-producing projects. Part of this amount has been used to support research undertakings which backstop the action programmes. The DANR administers the fund through a coordinating body called the National Food and Agricultural Council (NFAC) and the money has been made available to participating agencies within and outside the DANR.

Other major sources of funds are those derived from the sale of sugar, timber, tobacco, and coconut. The fees imposed on the sale of these products in the domestic and international markets support research and development of the specific commodities from which the earnings were derived. Such funds support agencies such as the Philippines Sugar Institute, Forest Products Industry Development Commission, Philippine Tobacco Administration and the Philippine Coconut Administration.

Manpower Resources

The manpower and staff capability varies with each research organisation. Colleges and universities and a few other agencies have regular programmes for

staff development and thus have developed strong pools of technical manpower, both at the baccalaureate and graduate levels. Most of the personnel with advanced degrees in agriculture are connected with the colleges and universities. On the other hand, the bureaus under the DANR have relatively few staff with graduate training for research.

Moderate to excellent graduate training programmes for many disciplines in agriculture are offered by local universities. With additional support, mainly in the form of scholarships, the universities can supply the number of trained graduates needed by the other agencies.

Research Facilities

Facilities for research vary among agencies. In general, facilities for conducting applied and adaptive research are adequate. More sophisticated, expensive equipment needed for basic research is generally lacking.

AREAS IN THE PRESENT AGRICULTURAL RESEARCH SYSTEM THAT NEED IMPROVEMENT

Coordination

As pointed out earlier, there is lack of coordination of efforts among the various research agencies. Research on production and utilisation of crops, livestock and fisheries is done independently by the universities, the DANR and the NSDB. This leads to unwise use of limited resources. Some degree of inter-agency cooperation among workers exists but in many instances this is on a very informal and person-to-person basis.

A formal system of inter-agency coordination must be established. The NSDB has not been duly recognised as a national coordinating body and has not carried out its function of coordination effectively. Part of the problem is that the NSDB has maintained a research role through its research arms, and therefore, as outside agencies view it, it has lost the element of impartiality as a coordinating and funding agency. To amplify the problem, the commissioners of three research institutes under the NSDB are Members of the Governing Board, a body which renders judgment on research priorities and funding. Since the research agencies have representations in the Governing Board and compete for funds and national recognition, any action by the Board may be misconstrued, by the outside agencies which the NSDB hopes to coordinate, to serve certain vested interests. The only alternative action for the NSDB is to free itself of its research function and play the role of an impartial coordinator. The NSDB should also be given enough powers to pursue its objective as a national coordinating body.

In the absence of a coordinating mechanism, coordination of work among research agencies may still be accomplished if the heads of the various units can come to a mutual understanding and agreement about the need to have an integrated national scheme of research and establish divisional lines of responsibility based on where each agency will best fit. There are, in fact, specific research programmes in the Philippines being undertaken jointly by workers representing a number of agencies which have proved very successful.

Mushrooming of Commodity Institutes

There is a tendency in the Philippines to create a separate institute for every crop or animal commodity of economic importance. The standard procedure is to use earnings generated from a given commodity industry exclusively for research

and development in the same commodity. We now have in the Philippines, the Philippine Tobacco Administration, Philippine Sugar Institute, Philippine Coconut Research Institute, Forest Products Industry Development Commission, Dairy Training and Research Institute, Fishery Research Centre and Rodent Research Centre.

While the system of creating commodity institutes has been very successful in other countries, in the Philippines this has contributed to excessive proliferation of efforts and duplication of existing work. This has also resulted in the dispersal of scarce technical manpower in the country. There are enough research organisations in existence which have the capability to take on added responsibility, if given adequate support, and all that is necessary is for the government to channel the additional earnings from the various industries to these agencies.

Another disadvantage in the present trend of using earnings from industries specifically for a given commodity is that it inhibits the flexibility of research. Revenues from sugar cane and coconut products constitute a major source of funds for research. As a national policy, we must search for and develop new products for domestic use and for additional export. When the fiscal resources are tied down to specific crop undertakings such diversification is not possible. A better alternative would be for the government to put all the earnings from the various industries into a common fund, probably the existing Special Fund, to be used in any undertaking that the economic situation may warrant. In that way research efforts will be more responsive to the changing needs of the country.

Relevance to National Needs

The national government has set a four-year programme to expand and maintain gains made in rice production and intensify production of corn, feedgrains (e.g. sorghum and soybeans), fruits for export, vegetables, livestock and fishery. Some of the national research organisations seem to have lost the flexibility to cope with new situations. Examination of research programmes of these national agencies reveals that the research efforts are not attuned to the needs of the national programme and research results or output cannot be expected to assist in backstopping the national efforts in production. There are many reasons for this. The resources for research, which are limited to start with, are spread out to many long-established projects, many of which are not relevant to the national needs. Too many research stations are being maintained. About 80% of the research budget is for salaries and very little remains for logistic support. Research activities are developed and selected on the basis of interests and areas in which available personnel have been trained instead of priorities based on national needs.

Agency Organisation

The research programmes for specific crops or livestock in some agencies are not well organised and lack the necessary balance and depth. There is little coordination among investigators working on the same commodity within the same organisation. There has been too much emphasis on production research and very little on the economic aspects when in fact marketing usually presents the greatest problem in commercial production. Research is not well balanced even within the narrower area of production. Some aspects are emphasised while other equally important problems are not. Development of needed packages of technology on the basis of research accomplishment becomes difficult. In short, the *systems analysis* approach is not employed.

Staff Development

Many of the national research agencies have not pursued a programme of development for their research personnel. In contrast, the colleges and universities have done a good job in providing adequate training opportunities for their staff. Thus, in one college of agriculture campus there is a concentration of 111 Ph.D.'s and a similar number with M.S. training. Related to the problem of staff training is that of providing the necessary incentives to attract and keep well-trained men. Salaries and fringe benefits in the government service are not competitive with those in the private sector.

In view of the better quality of research staff in the colleges and universities, one wonders if the educational institutions should not be given more responsibilities in research. Given adequate financial support, the educational institutions are in position to make a much more substantial contribution to national research output.

Coordination Between Research and Extension

There is no close coordination and linkage between research and extension. Research information developed in the various research agencies is not readily available to the end-users, except those results which find their way into technical and popular publications, since there is no regular and systematic system of processing and channelling information out to the public. The problem in the Philippines is that the extension arm of the government, the Agricultural Productivity Commission, exists as a separate entity and is not part of any research-oriented organisation.

THE CHANGING PICTURE IN AGRICULTURAL RESEARCH: STEPS BEING INITIATED TO IMPROVE THE SYSTEM

Agricultural Research Programme Review

In view of the pitfalls of the present resources for research, concrete measures are underway to correct and strengthen the situation in the Philippines. A national committee appointed by the President of the Republic has evaluated the food and agriculture research programme of the DANR. Recommendations have been made to correct the weakness and to strengthen the research programmes of the DANR.

In summary, the recommendations call for a major overhaul in the DANR set-up such as: (1) changes in personnel organisation; (2) change of budgetary and accounting systems; (3) institution of effective coordination of agency programmes; (4) consolidation of research resources; (5) central and effective control of research stations and funds; (6) changes in research evaluation procedures; and (7) establishment of linkages with other research, extension and education institutions. A strong recommendation was made for the adoption of the agri-business and 'systems' approach, using multi-disciplinary teams in solving agricultural problems.

With the present dynamic and very able leadership at the DANR, the necessary changes are forthcoming. The Secretary of the DANR has set aside an initial sum of 3 million pesos to support inter-disciplinary and inter-agency programmes that bear upon the needs of the four-year national goals of the government. The NSDB intends to contribute counterpart funds.

The second phase of the evaluation work of the Committee will attempt to look at the agricultural research programmes of agencies outside the DANR and see how a more viable and well-knit national research organisation can be institutionalised.

Reorganisation Plans

Another significant development in the Philippines is the National Reorganisation Plan now under study and in the hands of Congress. Among many other things, research institutions with similar functions would be merged and those which have been ineffectual would be abolished. The Agricultural Productivity Commission would be placed under the DANR.

Association of Colleges of Agriculture in the Philippines

The agricultural schools, colleges and universities have formally banded themselves into an association which meets annually to discuss programmes of education, research and extension. Also, a series of national seminars, participated in by the executives of the different educational institutions and national research agencies, have been conducted. These are based on the central theme of the need to establish linkages.

National Food and Agricultural Council

A pivotal point in the success of agricultural development is the degree with which action programmes are coordinated at the national level. Success in the rice programme would not have been possible without a central coordinating agency, the Rice and Corn Production Coordinating Council (RCPCC). The products of research at the International Rice Research Institute, the U.P. College of Agriculture and the Bureau of Plant Industry were harnessed and mobilised, together with all the resources of the supportive segments, i.e. the Agricultural Productivity Commission, Agricultural Credit Administration, the rural banks, the Development Bank of the Philippines and the fertiliser companies, into a unified national rice production programme. Self-sufficiency in rice production was achieved and plans for export are afoot. The same type of approach has been expanded to include the production of corn, feedstuffs, vegetables, livestock and fishery. All government programmes in agriculture are now coordinated by the National Food and Agriculture Council (NFAC).

Some degree of agency cooperation in research and development has been achieved and has produced very encouraging results. We have developed the 'minikit' programmes of applied research in rice, corn, soybeans and sorghum. The various inputs of variety, fertiliser, insecticide and herbicide are packed in neatly labelled boxes for distribution to selected growing areas. The personnel of the U.P. College of Agriculture (UPCA), the Bureau of Plant Industry (BPI) and the Agricultural Productivity Commission (APC) assemble the packages. The fertiliser and chemical companies provide the fertilisers, insecticides and herbicides. The 'minikit' packages are distributed to farmers by the APC and the BPI personnel in selected areas under their respective control. Selected farmer-cooperators grow the 'minikit' trials under close supervision of the APC and BPI technicians. The data are fed back to the UPCA for evaluation. These applied trials, grown all over the country, not only provide additional information on varietal adaptation but also serve as a demonstration trial or show window and as a source of new seed for the farming communities.

Another form of a joint undertaking pertaining to extension work and information dissemination has also been forged. The extension personnel of the BPI, BAI and the APC go regularly to the UPCA for short-duration training on the latest methods of crop and livestock production. This is necessary for effective extension work at the farm level. Also, the four agencies participate jointly in preparing extension publications. We now have annual volumes of *Philippine Recommends* for rice and corn. The UPCA and IRRI collaborated to produce the Rice Production Manual which now has an internationl circulation.

There are still uncounted opportunities for cooperative ventures in agricultural development. Our initial successes have given full encouragement and expectation that in the foreseeable future a more lasting relationship among government agencies and a closer partnership with the private sector will prevail and benefit the people whom we all want to serve.

In closing, I just would like to deliver the message: 'In the Philippines, the air is rife and resounds with cries for change. Changes have been slow in coming, but the tempo of change is picking up. We are changing. We must!'

APPENDIX

LIST OF AGENCIES CONDUCTING AGRICULTURAL RESEARCH IN THE PHILIPPINES

I Department of Agriculture and Natural Resources (DANR)

1. Bureau of Agricultural Economics (BAEcon)
2. Bureau of Animal Industry (BAI)
3. Bureau of Forestry (BF)
4. Bureau of Plant Industry (BPI)
5. Bureau of Soils (BS)
6. Philippine Fisheries Commission (PFC)
7. Philippine Sugar Institute (Philsugin)
8. Philippine Tobacco Administration (PTA)
9. Reforestation Administration (RA)
10. Parks and Wildlife Office (PWO)
11. Abaca and Other Fibres Development Board (AFDB)
12. National Food and Agriculture Council (NFAC)*

II National Science Development Board (NSDB)

1. National Institute of Science and Technology (NIST)
   a. Food and Nutrition Research Council (FNRC)
   b. Agricultural Research Centre (ARC)
2. Philippine Atomic Energy Commission (PAEC)
3. Philippine Coconut Research Institute (Philcorin)
4. Forest Products Research and Industry Development Commission (Forpridecom)

III Office of the President

1. National Irrigation Administration (NIA)
2. Agricultural Productivity Commission (APC)**

IV Other offices

1. National Economic Council of the Philippines (NEC)
2. National Research Council of the Philippines (NRCP)***
3. The International Rice Research Institute (IRRI), private

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* A coordinating office for action programmes in food production. It administers funds for research which supports the action programmes.

** An extension service agency.

*** A planning body which administers funds for basic research.

V *Colleges and Universities*

1. Araneta University, private
2. Central Luzon State University
3. Central Mindanao University
4. Central Philippine University, private
5. Mindanao Institute of Technology
6. Mindanao State University
7. Silliman University, private
8. University of the Philippines
   a. College of Agriculture
   b. College of Fisheries
   c. College of Veterinary Medicine
10. Xavier University

VI *Commercial Firms*

1. Dole Philippines (Dole subsidiary)
2. Philippine Packing Corporation (Del Monte subsidiary)
3. Stanfilco (Standard Fruit Company subsidiary)
4. Hijo Banana Plantation
5. Menzi Company (Rubber & Coconuts)
6. Yulo & Sons (Sugar cane & livestock)
7. Victorias Milling (Sugar cane)
8. Blue Bar Coconut (Vegetable oils)
9. Philippine Refining Company (Vegetable oils)
10. Ansa Farm (Livestock)
11. ESFAC (Fertilisers and chemicals)
12. Shell Philippines
13. Dow Philippines
14. Cyanamid Philippines

Agricultural Research Organisations in Taiwan

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Taiwan has made noteworthy progress in agriculture since the end of World War II. Agricultural science and technology developed by various research organisations and supported by farmers' organisations and island-wide extension programmes are by far the most important factors in Taiwan's agricultural growth.

The provincial agricultural research organisations are relatively more in number. Administered by the Provincial Department of Agriculture and Forestry (PDAF) are the Taiwan Agricultural Research Institute (TARI), seven District Agricultural Improvement Stations (DAIS), the Tea Experiment Station and the Sericultural Experiment Station. The Sugar Experiment Station and the Tobacco Research Institute are administered by the Taiwan Sugar Corporation and the Taiwan Monopoly Bureau respectively, both government enterprises. In addition, a College of Agriculture of the Provincial Chung Hsing University is administered by the Provincial Department of Education.

At the national level, the College of Agriculture of the National Taiwan University and the Institute of Botany, Academia Sinica are the organisations related to agricultural research. The distribution of the Taiwan agricultural research institutes is shown in *Appendix I*.

In this paper, the structures, activities and relationships described are confined to those relating to crop research; no fishery, forestry and animal research are dealt with.

PROVINCIAL AGRICULTURAL RESEARCH ORGANISATIONS

Taiwan Agricultural Research Institute

The Taiwan Agricultural Research Institute (TARI) was established in 1895 as the provincial agricultural research organisation. It was given its present name after World War II and was directly administered by the Provincial Government. TARI has been under the administration of the Provincial Department of Agriculture and Forestry (PDAF) since 1949.

At present, TARI has six technical departments, agronomy, horticulture, agricultural chemistry, applied zoology, plant pathology and agricultural machinery. It has four branch stations, Shihlin Horticultural Experiment Station, Chiayi Agricultural Experiment Station, Tainan Fiber Crops Experiment Station, and Fengshan Tropical Horticultural Experiment Station, with a total of 252 technical staff members. The research funds are mainly from the provincial government. Part of them are in the form of grants from the Joint Commission on Rural Reconstruction (JCRR) for selected projects.

The research activities undertaken by the TARI headquarters are either basic or applied, in the fields of breeding and genetics, crop physiology, soil fertility, soil chemistry and physics, soil survey, plant nutrition, disease and pest control, toxicology, biological control and agricultural machinery. In addition, the plant pathology department is also responsible for mushroom research, e.g. varietal and cultural improvement, spawn making, disease and insect studies, all of which contributed to the rapid development of the Taiwan mushroom industry. The crops studied are rice, peanuts, soybean, corn, citrus, vegetables and other special crops.

The Shihlin Horticultural Experiment Station, located in suburban Taipei, is the only floricultural research organisation and it has departments on floriculture, vegetables and plant protection. It is widely known for the study of orchids and other flowers in the tropical region. Other investigations on vegetables and citrus are being conducted.

The Chiayi Agricultural Experiment Station with three technical departments, agronomy, horticulture and plant protection, is undertaking both field and horticultural crops research. It is a well-known centre, both nationally and internationally, of sweet potato research.

A great number of new varieties of high yielding capability and with high-carotine content and good table quality have been developed by the application of both conventional and new techniques of cross breeding. The improvement of rice, especially the development of blast and plant hopper resistant varieties, is also a main objective of the station. The horticultural crop research workers devote most of their time to improving banana, papaya, and other tropical fruits of Chinese origin e.g. lichi and longan, etc. A variety of tropical fruit trees are maintained in the orchard for experimentation; we hope to develop new tropical fruits.

Research on fibre crops for clothing and industrial uses, such as jute, hemp, kenaf, cotton, flax, etc. is carried out by the Fiber Crops Experiment Station in Tainan. The Station has four departments; clothing fibre crops, industrial fibre crops, plant protection and fibre machinery. Many fibre crop varieties have been already developed for commercial use. Studies on the development of nematode-resistant hemp are well underway, with the cooperative efforts of pathologists and breeders. In addition, there is a well equipped fibre-quality testing laboratory which also serves the public.

Pineapple, banana, and papaya research are conducted by the Fengshan Tropical Horticultural Experiment Station in the extreme tropical south of Taiwan. The rapid increase of pineapple production in Taiwan is largely the contribution of this station. The well-known seedless watermelon is also the result of research by the Fengshan THES. A number of improved varieties of cabbage, cauliflower, radish and other vegetables have been developed.

District Agricultural Improvement Stations

Under the administration of the PDAF and working closely with the TARI are seven District Agricultural Improvement Stations in the districts of Taipei, Hsinchu, Taichung, Tainan, Kaohsiung, Taitung and Hualien *(see Appendix I).*

The DIAS's are primarily responsible for experiments on local problems and extension services.

Each station comprises four technical departments, agronomy, horticulture, plant protection and animal husbandry, and one extension service division carrying out programmes on the improvement of varieties and cultural practices, on pesticides, fertilisers and herbicides to meet local needs. These stations also cooperate with the TARI in conducting province-wide regional tests on varieties and fertilisers. The DAIS's have made a number of valuable contributions to the progress of Taiwan's agriculture, including, (1) the rice varieties, Taichung Native No. 1 and Tainan No. 5, (2) corn hybrids Tainan, Nos. 5, 8, 9, and, 10, (3) peanut varieties Tainan Nos. 3 and 9, (4) sorghum hybrids Taichung Nos. 1, 2 and 3, (5) onion varieties from Taipei DAIS, (6) millet varieties from Taitung DAIS, and (7) the successful culture of muskmelon.

The extension division serves as a bridge between research organisations and the Farmers' Associations through which the technical information and guidance are disseminated to the farm level through discussion meetings, demonstrations and other special gatherings.

Taiwan Tea Experiment Station

The Tea Experiment Station was established in 1903 and became a branch station of the TARI in 1921. However, since 1969, because of the increasing importance of tea research, the Tea Experiment Station has been administratively independent from TARI and under the direct supervision of the PDAF. It has four departments, breeding and agronomy, tea manufacture, tea machinery and extension to carry out research and extension on both black and green teas and development of machinery for the mechanisation of tea plantations and fertilisation of tea bushes. New tea varieties and machines for mechanised tea harvesting are the most prominent contributions of the Station.

There are two branch stations, the Yuchih Black Tea Station dealing with improvement of black tea varieties and the Linkou Branch Station which conducts green tea research and training of tea workers.

Taiwan Sericultural Experiment Station

This Station was founded in Taipei in 1910 under the name of the Mulberry Seedling Cultivation Station. It has been reorganised a number of times. It acquired the present name Sericultural Experiment Station in 1949. It is now a subordinate organisation of the PDAF and is active in all phases of sericultural research and extension work.

GOVERNMENT RESEARCH ORGANISATIONS

Taiwan Sugar Experiment Station

The Taiwan Sugar Experiment Station was established in 1910. After World War II, the Station was operated by the Provincial Government. It was incorporated

into the Taiwan Sugar Corporation in 1948. The Station has four departments, breeding, agronomy, plant protection and industrial chemistry, and three branch stations.

In view of the need to increase sugar production as part of Taiwan's agricultural development, the Taiwan SES is striving to attain the following goals: (1) To help farmers increase cane yields, shorten the growing period of the crop, and improve intercropping systems. (2) To boost productivity of plantations operated by the Taiwan Sugar Corporation. (3) To raise the efficiency of sugar mills. (4) To develop diversification of the sugar industry by utilising available resources, estates and equipment of the sugar mills.

The Station's laboratories and experimental farm occupy 500 hectares. All laboratories are very well equipped for a wide range of basic and applied research. The library contains 30,000 volumes of books and periodicals on the world literature in sugar production and processing. At present there are 140 scientists and 205 technicians working at this Station. The research funds come exclusively from the Taiwan Sugar Corporation which exports sugar to a world wide market.

A number of research contributions have been made by this Station. The development of 30 new sugarcane varieties, F135 to F164, and the release of the introduced variety, N:co 310 which saved the sugar industry during the period of 1956-1962 when up to 90% of the total acreage was planted to this variety. Since 1962, the new varieties F146, F152, F156, F161 and F164 have been the predominant ones for commercial planting.

Irrigation and fertilisers have been very important in increasing sugarcane yield. Plant pathologists have been able to identify the causal agent of white leaf disease of sugarcane as a mycoplasma which is transmitted by leafhoppers, and have developed measures to control the leaf blight. The control of the sugarcane borer by releasing wasps has been very effective. The use of herbicides has greatly reduced the cost of sugarcane production. In the industrial field, it was found that the use of cation exchange resin for treatment of the carbonated syrup could reduce the ash content of white sugar and some defoaming agents could solve the foaming problem and bad filterability in refining raw sugar.

Taiwan Tobacco Research Institute

The Tobacco Research Institute was founded in 1917 with its headquarters in suburban Taichung which was the centre of tobacco production. This Institute is a subordinate organisation of the Taiwan Tobacco and Wine Monopoly Bureau which controls all phases of the tobacco industry, e.g. production, purchase of leaf tobacco and sale of tobacco products. The Institute has three departments, breeding and agronomy, chemistry and processing and pest control, with a total of 55 scientists and technicians, to conduct research on tobacco variety improvement, fertilisers, tobacco chemistry and physiology, curing methods and measures for pest control. In addition, there are two branch stations, at Pingtung and Hualien, for research in southern and eastern Taiwan respectively.

The Institute also assists the Monopoly Bureau's extension agents by providing technical information and sometimes giving direct guidance to tobacco growers.

This Institute has developed varieties resistant to tobacco mosaic virus and powdery mildew. The virus once threatened the Taiwan tobacco industry. Large

scale breeding programmes on CMV and frogeye resistance are now being conducted. Studies on fertiliser formulations for tobacco and on the chemical components in relation to quality are conducted as a basis for production of better quality of leaf tobacco.

AGRICULTURAL RESEARCH IN UNIVERSITIES

There are two colleges of agriculture, the National Taiwan University in Taipei and the Provincial Chung Hsing University in Taichung. Both are responsible for training agricultural scientists and conducting research.

National Taiwan University

The College of Agriculture of the National Taiwan University was known as the Faculty of Science and Agriculture when the University was founded in 1928. It was reorganised into its present form following the retrocession of Taiwan to China in 1945. With the expansion of the College in recent years it now has ten departments, agricultural chemistry, agricultural economics, agricultural engineering, agricultural extension, agronomy, animal husbandry, forestry, horticulture, plant pathology and entomology, and veterinary medicine. All departments offer B.S. and advanced degrees. In addition, there are ten subsidiary units attached to the College for teaching and research; they are the agricultural experiment station, the highland experiment farm, the university veterinary hospital, the forest experiment station, the hydraulic research laboratory, the aerial survey training centre, the farm machine shop, the agricultural exhibition hall, the radioisotope laboratory and the phytotron.

The faculty totals 142 professors and associate professors, 40 instructors and a number of assistants from the College of Agriculture. They are primarily responsible for teaching. However, all the teaching staff is encouraged to undertake specific research because of the importance of research to agricultural development and advances in technology.

Since the institution is a national one, it is financed by the national government. Only a very small fraction of the university budget is allocated for research, with the greater part of the research funds furnished by the National Science Council and the JCRR in the form of research grants. Other government agencies and private enterprises also provide money for carrying out cooperative research projects on selected problems. Research projects financed by University funds are usually basic in nature whereas those financed by other agencies are, as a general rule, more practical or applied. There are more than one hundred projects undertaken by the College staff each year.

The University does not participate directly in extension work which is the responsibility of the PDAF. However, some types of extension services are frequently rendered in the form of consultations, lectures in various training programmes and offering one-year courses at college level to agricultural technicians or extension workers from the DAIS's and the Farmers' Association in order to bring them up-to-date with new knowledge and techniques.

Taiwan Provincial Chung Hsing University

After the retrocession of Taiwan to China in 1945, the Taiwan Provincial Agricultural Junior College was established in Taichung by expanding the School of Agriculture and Forestry. It was reorganised in 1946 as the Taiwan Provincial

College of Agriculture. The College was elevated to become the Taiwan Chung Hsing University in 1961, following the foundation of the College of Science and Engineering on the Taichung campus, and the consolidation of the Colleges of Law and Commerce at Taipei.

The College now has eleven departments, agronomy, horticulture, forestry, agricultural economics, agricultural education, entomology, plant pathology, soils, water and soils conservation, animal husbandry and food technology. All departments offer the B.S. degree. In addition, the departments of agronomy, soils, plant pathology and agricultural economics offer the master's degree. Several subsidiary units, an agricultural experiment station, forest experiment stations (with 8176 hectares of forest), fruit tree orchard, food processing plant and a machine shop are available for teaching and research.

The College has 80 professors and associate professors, 31 instructors and a number of assistants and technicians who teach and do research. It is financed mainly by the Provincial Government but research funds are mostly from the National Science Council, the JCRR and other government and private agencies. The research projects vary according to the facilities and personnel available in each department.

ACADEMIA SINICA

Academia Sinica, the nation's highest academic research body, was founded in Nanking, China in 1928. Before the war it consisted of ten research institutes. During the war years, the Academia Sinica continued to function with the institutes scattered in the south-western provinces of Szechwan, Kweichow and Kwangsi. After the war, the number of institutes increased to 13 at the time the Chinese communists overran the mainland.

Only two institutes, (1) mathematics and (2) history and philology moved intact to Taiwan. Despite the adverse conditions, Academia Sinica has since reactivated or inaugurated seven more institutes. The present nine institutes are history and philology, mathematics, physics, botany, chemistry, zoology, ethnology, modern history and economics. The Institute of Botany is related to agricultural research.

Since the re-establishment in 1962 of the Institute of Botany, it has acquired nine laboratories, in cytogenetics, plant breeding, plant physiology, plant pathology, marine phycology, biometry, plant biochemistry, microbiology and molecular biology. Research in this Institute is fundamental rather than applied: nevertheless it has great impetus on further agricultural development in Taiwan.

THE JOINT COMMISSION ON RURAL RECONSTRUCTION

The Joint Commission on Rural Reconstruction is an organisation unique to Taiwan and pertinent to agricultural research. It has made great contributions to Taiwan's agricultural development through the introduction and promotion of agricultural science and technology. It is a Chinese-American organisation, authorised by Public Law 472 of the 80th U.S. Congress and established in 1948 following the Exchange of Notes between the Governments of the Republic of China and the United States. The organisation was created initially to carry out a pioneering

type of rural reconstruction and agricultural development programme on mainland China.

In 1949, the JCRR moved to Taipei to engage in a similar programme of development on Taiwan.

The Joint Commission is composed of three commissioners, two Chinese and one American. It has a staff of approximately 115 Chinese agricultural specialists who work in the fields of irrigation and land reclamation, crop and livestock production, forestry, fishery, rural health, marketing, agricultural extension, agricultural economics, farmers' organisations, etc. American technicians have been engaged frequently as short term consultants. The U.S. economic aid to China was phased out in 1965, but the JCRR is being continued on a bi-national basis by mutual agreement. The organisation performs many of the functions of the Ministry of Agriculture for the National Government of China and its programme is financed by the Sino-American Fund for Economic and Social Development, established with the residuary fund of the U.S. economic aid of previous years. Limited support is also available from PL 480 and other international establishments.

During the past two decades, the JCRR has given technical and financial assistance to more than 6,500 agricultural and rural community improvement projects undertaken by public and private agencies and organisations. A number of the JCRR-supported projects have contributed to the promotion of Taiwan's intensive multiple cropping system, the improvement of crop varieties, the control of field pests and livestock diseases, the establishment of marketing systems, the introduction of soil conservation practices and the expansion of irrigation and flood control facilities, etc.

The JCRR is now concentrating its efforts on selected projects which will increase the output and quality of agricultural products for domestic use and export. Particular emphasis will be placed on innovative and promotive types of agricultural development projects that are beyond the technical and financial capabilities of regular Chinese agricultural agencies.

PROJECTED REGIONAL RESEARCH ORGANISATIONS

Asian Vegetable Research and Development Centre

In view of the inadequate nutritional level of Asian people, there is an urgent need to step up production of protective food crops through scientific research. Vegetables are a ready source of plant proteins, minerals and vitamins. The AID/Washington initiated the Asian Vegetable Development Centre in 1963 and it is now established in Taiwan. The research programme of the Centre will concentrate on improvement of fresh vegetable production and marketing. Simple and practical forms of processing will also be stressed.

Plant Protection Centre

Although a well organised government scheme for plant protection is in existence and farmers are thoroughly advised on the timing and use of pesticides under this system, the large quantity of pesticides used has created many serious and unexpected problems. Research on these problems is lagging behind the actual needs for applying control measures.

The research, demonstrations and training on pest control carried out in Taiwan are rather fragmentary and a broad research programme should be initiated to keep research and the application of control measures closely linked. For these purposes, a Plant Protection Centre is being established in Taiwan with the assistance of the UNDP. The Centre will be part of the enlarged Agricultural Research Institute and will concentrate on major phases of research, training and demonstration.

Bamboo Research Institute

The bamboo is a very important crop in Asia and large acreages of bamboo are grown in Taiwan. Because of its versatility in uses, and the character of fast growing, it has very high economic value and has received more attention in recent years. However, research on production and utilisation leaves much to be desired and a Bamboo Research Institute has been proposed to conduct research on cultivation, utilisation and chemistry, and to train technicians.

The proposed Bamboo Research Institute will be on an international basis. It is still in the planning stage and sources of funds and the form of organisation are yet to be determined.

THE PROPOSED PROVINCIAL AGRICULTURAL RESEARCH SYSTEM IN TAIWAN

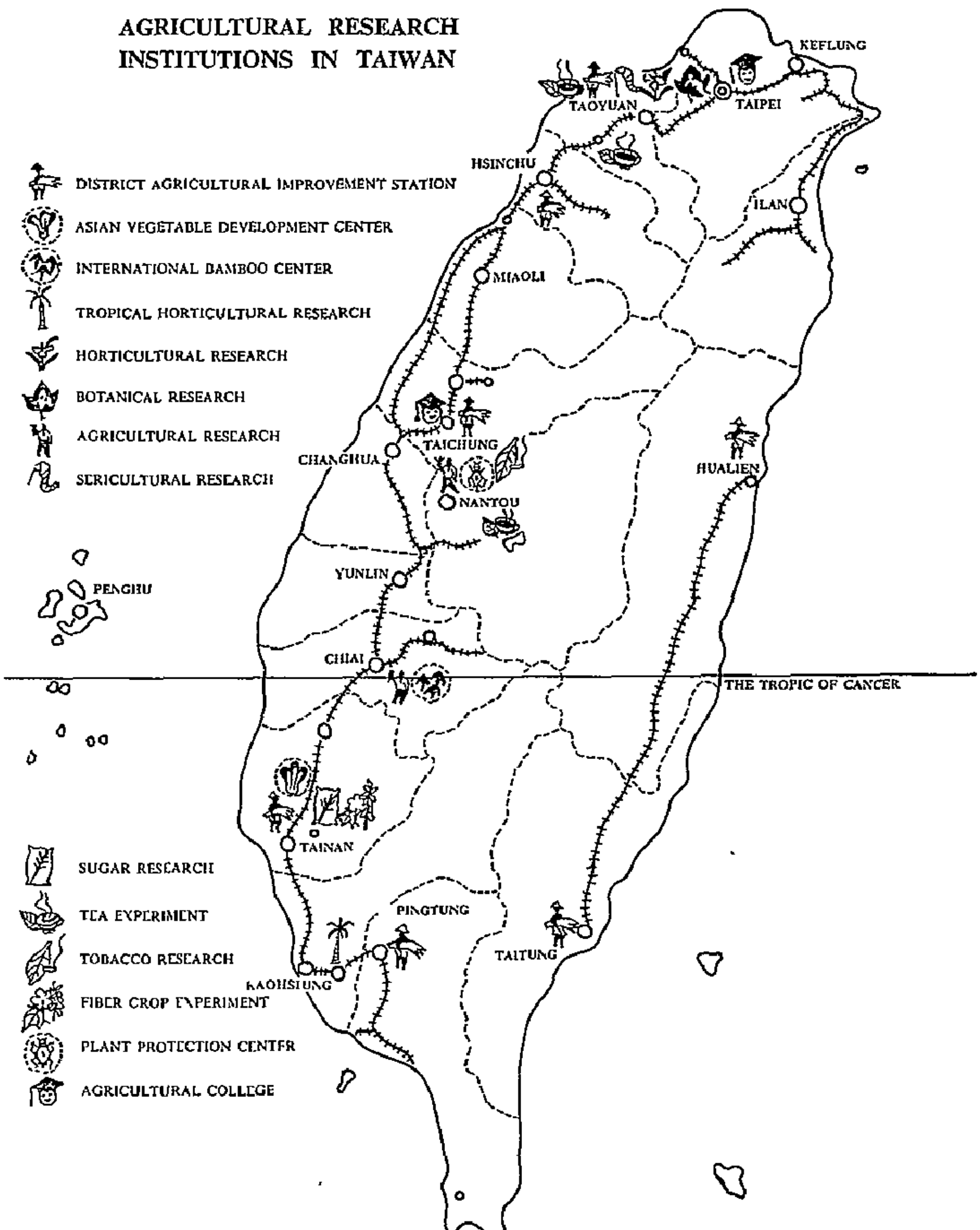
In view of the importance of research in further agricultural development, the agricultural research organisations in Taiwan are considered inadequate to meet future needs. Research work is sometimes duplicated and cooperation among different organisations under the PDAF is often restricted because of organisational barriers.

There is a shortage of well-trained scientists, they are scattered and this makes implementation of team projects difficult. The government is considering a reorganisation of existing agricultural organisations under the administration of PDAF into a new form.

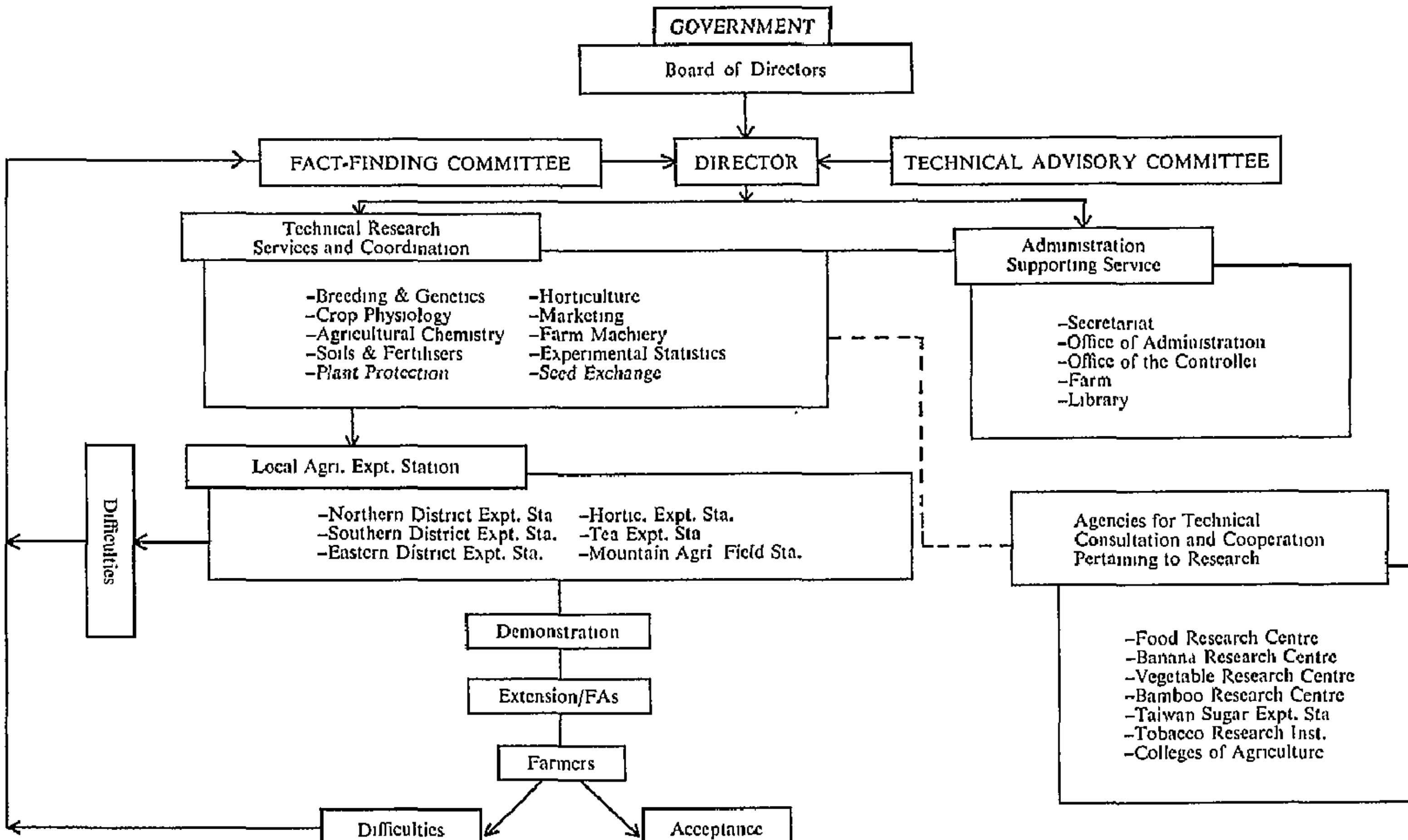
Various suggestions are now available. The most popular proposal suggests that there be an enlarged agricultural research organisation to serve as a centre to lead the Island-wide research projects under which the existing agricultural research organisations, including the TARI, would be merged. The branch stations should be consolidated to reduce their number from seven to three or four, for conducting regional research projects and extension, to minimise institutional barriers. Some of the experiment stations for special crops would remain unchanged. After the consolidation the better-qualified scientists would be located in the centre to carry out innovative research projects under a better environment. The branch stations would undertake more practical and localised research problems and carry out all extension work.

The expanded agricultural research organisation would have its facilities increased and the pay scale would be improved in order to recruit more scientists. The funds would be provided from both national and provincial governments. Part of the funds should also be made available from export earnings.

The proposed new organisation for the agricultural research and extension system in Taiwan which would appear to be most acceptable is shown in *Appendix II*.


AGRICULTURAL RESEARCH INSTITUTIONS IN TAIWAN
DISTRICT AGRICULTURAL IMPROVEMENT STATION
ASIAN VEGETABLE DEVELOPMENT CENTER
INTERNATIONAL BAMBOO CENTER
TROPICAL HORTICULTURAL RESEARCH
HORTICULTURAL RESEARCH
BOTANICAL RESEARCH
AGRICULTURAL RESEARCH
SERICULTURAL RESEARCH
SUGAR RESEARCH
TEA EXPERIMENT
TOBACCO RESEARCH
FIBER CROP EXPERIMENT
PLANT PROTECTION CENTER
AGRICULTURAL COLLEGE
KEELUNG
TAIPEI
TAOYUAN
HSINCHU
ILAN
MIAOLI
TAICHUNG
CHANGHUA
NANTOU
HUALIEN
YUNLIN
PENGHU
CHIAI
THE TROPIC OF CANCER
TAINAN
PINGTUNG
TAITUNG
KAOHSIUNG

PROPOSED AGRICULTURAL RESEARCH AND EXTENSION SYSTEM IN TAIWAN



The Planning and Implementation of National Research Programmes

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Since the organisation part of agricultural research in India has already been dealt with by Mr. Menon, I shall concentrate on four factors which I consider to be essential in the design and operation of a successful research system. The first relates to the identification of problems and assigning of priorities. The second is development of the research strategy itself. Thirdly, is the execution. And lastly, the delivery of research results.

RESEARCH PRIORITIES

India is a big continent, there are varied problems, and it is very difficult to say which are most important except in relation to a specific region. We can identify the attainment of food self-sufficiency as having number one priority in all of our research projects in India. Closely related is the stability of production — from a situation of being self-sufficient in one year and having famine in the next year it is necessary to achieve permanent self-sufficiency.

The income potential of small farms must be increased if the economic lot of our farming community is to be improved. As is well known, the majority of our land holdings are rather small in size. In fact, 75% of our land holdings are below two hectares.

Another major problem which is now threatening the political and economic stability of the country is the provision of remunerative and productive employment, not only for the literates but even more important for the many semi-literates and illiterates. In fact, unplanned migration of landless labour from villages to cities has been one of the major causes of urban slums and urban unrest. This is best exemplified by the situation of Calcutta city.

Increasing the efficiency of farming is one of the principal pre-occupations of our current research efforts. I am using 'the efficiency of farming' in economic terms. In other words, efficiency as measured by the return a farmer gets from his investment in inputs, which brings down the cost of produce to a level which is remunerative to the farmers yet reasonable to the consumers.

We are increasingly aware of the problem of protein-calorie malnutrition, a matter of concern in all developing nations but of critical importance in India. This relates not merely to health but also to family planning programmes which have agricultural implications. It is becoming clear from various studies that better nutrition of the children is the foundation upon which successful family planning programmes can be erected, for the simple reason that child mortality is the determining factor in acceptance of family planning by the greater majority of the rural population.

STRATEGY

When we are thinking at a national level there has to be a considerable amount of flexibility in the research system itself to embrace the combination of major problems. A strategy is devised related to the total national requirements. Once the end point or objectives are clear and precisely defined, much of the problem of the research director, and of the research worker is resolved. The major issue is then to determine the type of strategy to adopt to achieve the overall objectives.

The strategy with a given crop, or within a region, might vary. Let me give one example. Cotton is important to this country since clothing is almost as essential as food. In order to devise a research programme to improve cotton production the research planners must know the likely patterns of demand for various kinds of cotton goods. Representatives of the cotton industry and economists have to be consulted to determine how much cotton will be needed above the staple length of one inch, how much of other staple lengths, and of particular qualities. We need this type of information before we decide upon what strategy to adopt for a specific crop improvement and production research programme. When this was done the picture given in the following Table emerged.

RAW COTTON REQUIREMENTS

Staple length category	Expected consumption in 1975	
	1,000 bales of 180 kgs.	%
1-3/16″ and above	392	4.9
1″ and above	1,424	17.8
7/8″ to 15/16″	3,224	40.3
12/16″ to 13/16″	2,616	32.7
11/16″ and below	344*	4.3
Total	8,000	100.0

*About 3 lakh bales of short-staple cottons are exported.

In so far as possible we try to follow a philosophy of shaping the programme to meet a given objective and not worshipping a particular method or becoming a slave to a 'standard' approach. We endeavour to develop a method which is

appropriate to the problem and to the circumstances in which the problem has to be solved. One important aspect of research strategy is the formulation of fully integrated, multi-disciplinary projects. Recently we have developed a national project formulation centre. Even though assistance from aid-giving agencies is available it cannot be utilised unless there are worthwhile projects formulated by the scientific workers who will carry them out. So the special attention to project formulation, I think, is an essential ingredient of a successful research system.

PROGRAMME EXECUTION

Planning councils and committees can agree upon important problems but ultimately, the critical factor lies at the level of execution. In the execution of a research programme the first important thing, of course, is the availability of qualified scientific manpower. Secondly, a requisite of a successful research system — I want to say that we have not yet achieved a high level of perfection in this regard — is to develop a pattern of inter-disciplinary coordination within the scientific team so that it performs like a symphony orchestra. You may have a large number of research workers, each with a high degree of individual competence, but what is more important is the combined excellence of the whole group. As in the case of the symphony orchestra, each of the performers or scientists will be good or bad in their own way, and so the capability of the conductor is especially important.

In the execution or implementation of a research programme it is essential to keep in mind the goals or ultimate objectives. The research leader must recognise the relevance of the research efforts. He will have to consider ultimately when his efforts have borne fruit and decide how they can best be applied under field conditions. This emphasises the importance of having effective 'national research systems' because the fitting of solutions to agricultural problems cannot be done in a global way. This is where the individual peculiarities or situations of the particular country will come into play.

APPLICATION AND USE

The delivery system — for the effective dissemination of research results — is an exceedingly important component of the national research system to which many countries, at least India, have not given detailed consideration until recently.

The delivery system is not only the extension of research results to farmers. It has also the critically important task of communicating or delivering the results of research to the policy maker. Ultimately, while there may be an excellent national research system the results of the research may not find proper or useful application because politicians and administrators might be quite ignorant about the implications of the research discovery. The scientist, therefore, has a dual responsibility, to carry out meaningful research and to put out the results in a way that will convince the policy maker to take pertinent follow-up action. A purely theoretical paper or report in a scientific journal cannot, obviously, be of use to the policy maker.

I would emphasise that one of the major problems we are facing in this country is not so much the communication of research results to the extension worker and the farmer but to the policy maker. Scientists will have to take a little more time and trouble to identify how to do this. One approach is to determine the economic potentials and interpret the whole research results in operational and socio-economic terms.

AGRICULTURAL RESEARCH AND DEVELOPMENT IN INDIA

I would like to review briefly some factors of significance in agricultural production in India.

Some coastal areas and also the Indo-Gangetic plains are characterised by a relatively high productivity and also high stability of production. But in the dry land farming districts, where the rainfall is below 30 inches annually, there is both severe instability of production and a large amount of landless labour. A major problem facing developing nations is that of employment and the many countries represented here will agree that the agriculture sector will have to provide the major avenue of employment in the foreseeable future. In terms of the number of people involved in the Asian region for whom jobs will have to be provided, the task is enormous.

Nutrition

One major factor I mentioned earlier was the protein-calorie malnutrition which has a critical impact on our national development. This is just being understood by the politicians and administrators. The fact that brain development of young children might be seriously and irreversibly affected by malnutrition is just being realised. In India we have a serious problem of calorie malnutrition and there is a controversy whether it is a calorie under-nutrition which is the mother of malnutrition, or whether there is protein deficiency also in addition to calorie insufficiency. In parts of India where rice is the staple, such as peninsular India or the southern parts of India, malnutrition is severe. In the middle part of India where wheat is a staple diet there is moderate malnutrition. In the region of the Punjab there is mild malnutrition because the milk supply is much better.

Intensive Agricultural Development Programmes

Due to our economic position we have to identify the most critical problems of priority action to accelerate development. One example from our experience in the last ten years, which will illustrate how we have approached this problem, is the case of rice and wheat production. I have divided this into four major periods, (1) pre-package, i.e., before the package programme or Intensive Agricultural Districts Programme was initiated in 1961, (2) the early IADP package period, 1962-65, (3) the drought years of 1965-67, and (4) the high-yielding varieties programme from 1967 onwards.

When the IADP project was introduced in the early 1960's much was expected out of it. But initial results were not as good as were anticipated. The reason for this was simple. What we called a package was not a good package in the sense that there was one very important missing ingredient — a variety which could respond to the rest of the inputs of the package. Our major effort, major thrust, was then placed on the identification of varieties which would respond to the rest of the package. When that was done, and in the case of the new wheat and rice varieties there has been a dramatic increase, the package of practices made the expected impact.

The new dwarf wheats supplied by Dr. Borlaug proved to be exceptional in their response to fertilizers and they gave high yields immediately, in the first year when they came to us. We knew that the first dwarf varieties, Lerma Rojo and

Sonora 64, had low acceptance from the consumers as well as the cultivators because of their red grains. Our people prefer the amber grains for making chapatis. That is why we started immediately to improve the grain type. Dr. Borlaug was kind enough to furnish not only the finished varieties, Lerma Rojo and Sonora 64, but also a large number of crosses as segregating populations. From these materials a series of varieties, Kalyan Sona, Sonalika, Safed Lerma and others were selected. At the same time we applied the mutation technique to produce additional mutants with amber grain colour and in this way Sharbati Sonora was developed from Sonora 64. This is what I meant in referring to a choice of a method which is suited to a particular context.

Dry Land Farming

Another important priority area is the dry land farming region. Again, here is a case where one has to have a whole team of scientists. One example is castor, which is a very important oilseed crop in certain areas of Telangana region in Andhra Pradesh which produces 80% of India's castor. This is a low yielding and high instability region. Once in three years rains may fail and the castor crops may be ruined. We had nearly 50 years of rainfall data awaiting analysis. On the basis of this analysis it was determined that if we had a castor variety which could be sown in the month of June and harvested by the end of September or early October then the possibility of the crop failing once in three years could be avoided. A suitable strategy was undertaken in developing the variety called Aruna which fits this growing period.

Protective Research

In the case of pest and disease control, these problems are considered in the All-India Workshops where plant breeders, pathologists, entomologists, and nematologists all meet together to devise coordinated strategy for control measures. Take for example sorghum, an important crop which occupies the largest land area next to rice. You ask the geneticist to deal with the pests and diseases to which he can develop resistance in varieties without difficulty. Then you ask the man in charge of pest control to name the pests and diseases for which safe, reliable and economic methods of chemical control are available. Lastly you ask the agronomists whether particular pests can be avoided provided you change the date of sowing. Now we can do this since more of the new varieties are relatively insensitive to photoperiod and temperatures. Then you work out a coordinated strategy which takes into account all of these potential control measures.

Model Agronomic Centres

Now that we have a coordinated project on each crop it is necessary to put the various results under test in combination to assess their total feasibility. We have set up 'Model Agronomic Centres' for this purpose.

From a large amount of data obtained on sorghum for the last 6 years, from 1963-1968, we found that the hybrids which we thought would do well only with water and fertilizers, did even better under rainfed conditions, without irrigation.

The very important lesson we are learning from these types of trials is that one need not sow a crop at a particular time because our ancestors and forefathers had been doing so. For example, in the case of maize hybrids and composites

we found that the winter season, which is not the traditional season for cultivation, gives a much higher yield. Ambar Composite gave 4881 kgs. per hectare during the monsoon season, when maize is cultivated normally, but 8577 kgs. per hectare were obtained during the winter season. Therefore, it has now become possible to change cropping systems or rotations. These model agronomic centres are used to fit new practices together.

Identification of Potentials of New Technology

It is important to translate the values and benefits of research in terms that are understood by the administrator and the politician. Our failure to do this is one of the reasons for the slow adoption of technology. The research worker has left very large gaps which can only be surmised by policy makers.

There are many benefits from research of practical value which we can publicise. The feeding trials showing the benefits of the high protein maize variety we expect to release shortly are of great potential public benefit. The new methods for control of pests, for example, on pulses, have a dramatic effect. The development of engineering technology is relevant in the field of agricultural engineering research, not so much for labour replacement but to increase efficiency of human energy and reduce human drudgery. This is the basic philosophy in our agricultural engineering research. For example, many farmers now have tubewells. They also are using chaff cutters. Normally the farmer or his wife or child operates the chaff cutter. Now we have shown that by a simple water wheel attached to the tubewell this type of drudgery can be easily removed. Similarly, simple reapers and bullock threshers have been designed to increase the efficiency of farmers and timeliness of operations.

In most developing nations there is a very high loss of grains in storage, and at harvest time in South East Asia there is usually much moisture in the grains. We have developed a very simple 'Pusa Bin' which can be adopted by the small farmer to bring the moisture down and improve the storage. In Indian agriculture our aim is to adapt sophisticated improved technology so that it can be used under our conditions. The 'package of practices' will involve a graded dose of sophistication, so that farmers in different levels of modernisation can all benefit.

The National Demonstration Programme

Finally, I wish to mention the extension function. When we started the high-yielding programmes in 1965-66 there was a good deal of scepticism among the politicians and the administrators. As enormous facilities are available at our Institute it was felt that the results obtained by the scientist cannot be reproduced in an average farmers' field. Hence, we decided that scientists should themselves lay out demonstrations in farmers' fields. This 'National Demonstration Programme' under the charge of Indian Council of Agricultural Research has become an important factor in the whole strategy of our agricultural development. The national demonstrations usually select the poorest men in the village so that the success of the technology cannot be attributed to the effects of affluence but to the technology itself. In the wheat production demonstrations, for example, the crop is sown with bullock-operated equipment. Similarly, we demonstrate improved dry farming methods of cultivation, to show the farmer how to conserve the limited soil moisture acquired from precipitation or rainfall.

International Cooperation

Now lastly I want to mention the international aspects of the Indian research programme. India is a veritable gold mine of germplasm. Dr. Chandler referred to the fact that many of the Indian rice varieties have very interesting characters. Even for maize, a crop from the New World, there is a large diversity in this country. There is, unfortunately, a rapid displacement of the plant wealth — old varieties and primitive types — by the new high-yielding varieties. So one major responsibility of a research system is to collect, preserve and make available to the farmers the best combinations of genetic characters in crop plants. Here the International Institutes have been very helpful. The U.S. Department of Agriculture, the International Rice Research Institute and CIMMYT all have played a very important role in human welfare by conserving a broad base of economic crop germplasm. This work should be expanded, so that the fruits of thousands of years of natural and human selection are not lost to posterity.

Restraints In Building National Research Capabilities

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As part of its world agricultural activity FAO is charged with advising member governments on the establishment and organisation, or reorganisation, of agricultural research services. To assist in this field a Sub-panel of Experts on the organisation and Administration of Agricultural Research was established. At the two meetings of this sub-panel, numerous factors militating against the establishment of sound research capability have been discussed and some general guide-lines have been developed. Further, comparative studies in various regions (including Asia and the Far East) have been conducted and these have also provided relevant material.

Two of the most authoritative works published in recent years on the subject of the organisation of agricultural research (a long neglected topic) are Dr. Isaac Arnon's 'Organisation and Administration of Agricultural Research' (1968) and Dr. Albert H. Moseman's 'Building Agricultural Research Systems in the Developing Nations' (1970). Both are quoted in this paper and due acknowledgement is made. Dr. Moseman has stated that 'deficiencies in existing national research capabilities in the developing countries involve multiple factors, many of which may seem minute, but for which there is no single major panacea. The nature and extent of such restraints can be determined only by a thorough-going study of each specific national situation.'

The purpose of this paper is to point-up generally accepted restraints, to indicate solutions already suggested and to initiate discussion which may lead to the suggestion of other solutions. Recognising the individual nature of national research organisations and consequently the existence of problems specific to perhaps only one country, it should nevertheless prove possible to formulate broad guide-lines within which national structures can be accommodated.

Broadly speaking, the components of any functional system can be divided into three major groups, each with inter-related and frequently inter-dependent constituents. For the initiation and development of a national agricultural research capability, therefore, the major considerations whould be as follows:

1. *Politico-social:* political stability, social climate, rural development plans and aspirations.

2. *Institutional:* systems of governmental organisation and administration, quasi-governmental (often including the universities sector) and the private sector.
3. *Resource availability:* financial, material and human.

No attempt will be, or should be, made to assign generalised priorities between the above groupings. Each of us, in thinking of our own system or former system would probably, as a first reaction, assign a different priority. Nevertheless it was suggested above to deal with a situation from initiation and in this circumstance political and administrative considerations must surely come first.

POLITICO-SOCIAL CONSIDERATIONS

The creation of a clear understanding by national political leaders of the indispensability of a sound national research programme must be the first step toward its establishment. Historically, many of the developing nations inherited existing systems from the former colonial power; in others, systems have been developed with the assistance of major commercial interests and international and bi-lateral assistance agencies. Neither the orientation nor the organisation of these 'imported' research systems have always proved to be the most apposite. Independence has given the opportunity for national level rethinking in the research field along with the general field of agricultural development; for example, the need to effect a change from emphasis on export cash crops to expanded food production.

Stability

In some countries there have been periods of varying length of political instability. There is an absolute necessity for a reasonable level of stability to ensure continuity in national development planning and in research. The extreme situation of lack of political stability causing chaos in national research systems is, fortunately, not common in this region, but in some countries, with every change of government, most government and university heads of departments and many senior research personnel are changed overnight. True, the displaced scientists normally continue employment in research with commercial companies and other non-governmental undertakings but the ensuing loss of momentum in research is very great and the wastage of trained manpower in the maintenance of two or more complete cadres is tremendous.

Fortunately, in most regions today, international and regional research organisations and technical assistance of one form or another can often ensure continuity where this is lacking or lost. But nothing can really replace continuity at the national level based on, if not a fully stable political climate, at least a permanent service lacking political affinities and sufficiently strong to have influence at the national planning level, no matter which government may be in power. As it is more often than not the economic planner who forms the bridge between research worker and politician there is a strong case for ensuring much closer liaison than currently exists between research departments and national economic planning bodies. There is thus a particular need for economists able to make a pragmatic approach to a country's research requirements.

Social climate

It is not only at the political level that the need to engender a favourable climate towards research exists. In the long run the farmer, as user of results,

and the ordinary citizen — whether rural or urban taxpayer — who pays for the research results, need to be convinced of the desirability of maintaining a properly financed research effort. That there is not, in most countries, a better understanding of the importance of research can be blamed in the main on the research workers themselves and their unfortunate tendency to think of themselves as 'above' such mundane consideration and aloof from the need to seek publicity. It is essential that the 'ivory tower' attitude so frequently aired as a criticism of research workers be thoroughly demolished, particularly in agricultural research where results have such far reaching human application. This campaign to spread information on what research is doing — open days at research stations, and closer liaison with rural sociologists and extensionists, is indispensible to the creation of a suitable climate for research work. Where agriculture accounts for perhaps up to 80% of the G.N.P. and the rural sector for probably 80% of the population, we cannot afford to disregard the farmer as a 'power in the land'.

INSTITUTIONAL CONSIDERATIONS

Governmental organisations

Institutional restraints are generally recognised as among the most important facing the developing countries striving to establish a research competence. However brilliant the individual research worker, however strong the funding of research from mineral or other resources of wealth, the fruits of research will not be fully exploited to the greater good of the farmer in the absence of a sound institutional structure. Such a structure for a functional agricultural research organisation should, according to Arnon, meet the following requirements:

'(a) Commitments to solving the problems of the agricultural community.

(b) Ability to carry out a balanced programme of research, covering both the urgent and day-to-day problems of agriculture as well as the long-term problems. This involves:

(1) Close contact with the Ministry responsible for agricultural policy and development.

(2) Readiness to carry out both applied and basic research according to the type of problem to be handled.

(3) Sufficient detachment from immediate pressure to be able to devote the necessary efforts to long-term and exploratory research.

(c) Ability to make the most efficient use of research personnel, equipment and funds. This involves:

(1) A central organisation that can effectively coordinate its work with a minimum of outside interference, and the avoidance of needless duplication of effort.

(2) Autonomy in the implementation of its research programme in order to ensure flexibility of administration with a minimum of outside bureaucratic interference and red tape.'

An examination of a number of existing national structures by FAO has revealed the existence of the following main types of organisation, the advantages and imposed restraints of each of which are indicated:

A. Research conducted by several subject matter departments dependent upon one or more ministries of state.

This type of organisation is often encountered in countries with several ministries, e.g. crop production, livestock, forestry, lands and water, etc., involved in the agricultural development sphere. In most cases each ministry has responsibility for its own research and, in the most exaggerated cases of fragmentation, separate subject matter research divisions are encountered within each ministry.

The prime disadvantage of this type of organisation is the lack of necessary coordination in practice, despite the defence raised for it that normal governmental inter-ministerial or inter-departmental machinery ensures adequate interchange of ideas. Two basic principles support the rejection of such a system. First, that the nature of research needed in developing countries requires the closest of team work on an inter-disciplinary basis and this pre-supposes a unified direction; secondly, the well-known principle that the operational and implementational problems of any undertaking increase in proportion to the number of bureaucratic units involved in the support of that undertaking.

The same criticisms apply, although perhaps to a lesser degree, to the conduct of research by several separate (usually subject matter) departments within a single ministry. Although initial coordination and overall planning may be better the practical conduct of programmes, especially the often necessary transfer of funds and personnel, will be no easier to achieve in the face of the general inflexibility of ministerial budgetary processes.

B. The centralisation of all agricultural research under a single specialised department of a ministry of agriculture has been adopted by many of the developing countries in various regions of the world.

Its advantages are obvious in that it permits the most effective utilisation of limited funds and personnel for the achievement of the policies of the ministry. It permits the closest possible collaboration between research workers and imbues them with a sense of participation in national plans.

Its restraints are perhaps less obvious to non-research workers. They are, in fact, those deterrents and frustrations inherent in a civil service such as inflexibility in administrative, accounting and supply procedures and a personnel system in which promotion depends all too often on seniority rather than ability. All are stultifying to the intuitive research worker and the result is frequently a mediocre government research establishment, with the best workers migrating to the universities or the private sector. The dangers of maintaining this type of system under usual civil service procedures are very real, therefore, and consideration should be given to the personnel and business management policies and procedures which will foster and promote research output.

C. By far the most confused situation, institutionally, is that in which one or more ministries and one or more specialised institutes conduct research independently and simultaneously. No matter how efficiently the institutes may be conducted, and despite their freedom from the restraints besetting public services, their very autonomy poses problems of coordination greater

than those existing under other systems. The inevitable competition between each other and with other government services for available staff, funds and facilities; the need to preserve individuality and the struggle for prestige — often achieved through unhealthy duplication of work on the same problems — raise great dangers for inefficient use of limited resources in the developing countries.

Unfortunately this type of organisation has become established through various causes, historical, political, even accidentally, in several developing countries. Only through the setting up of further machinery in the form of a strong national agricultural research council or similar coordinating body, can this diffuse system be made to function efficiently. In most cases, a complete restructuring is to be preferred to such super structures for 'coordination' which usually tend to dissipate scarce scientific man-power.

D. Where research is conducted by one specialised institute which is autonomous or semi-autonomous with respect to government ministries, a form adopted by very few countries as yet, most of the restraints inherent in the foregoing system are minimised. The institute receives and controls its own budget independently of the public service system; full coordination in programming and in operation team work is ensured; costly equipment is centralised and grouping of research talents in one place ensures the essential dialogue that stimulates efficient research and helps to lead to contentment amongst research workers. It is also much less influenced by political changes and free from the restraints so imposed. The one danger of such a system is that it may become too highly autonomous and thus out of touch with, and unresponsive to, the immediate needs of agricultural production.

As a result of their review of the above systems the FAO sub-panel came to the conclusion that council of perfection rested somewhere between types B and D. That both are more efficient than either of the other two forms was not disputed, but controversy remained over which type was most suited to development situations. In general, opinion seemed inclined toward the establishment of a central research department of the ministry of agriculture in the early days of development of a research system, leading gradually to the granting of more autonomy to that department. Then, by a gradual process, a national agricultural research institute would be brought into being, tied to the ministry but separated from the worst restraints of the civil service system, with the whole being coordinated with university and other research by a national agricultural research council.

The Universities

No review of agricultural research organisation at the national level can be complete without including the role, in many cases a major one, played by the universities. The traditional role of the university in research differs in those developed countries which have made the greatest contribution to development through their bi-lateral technical assistance programmes. Consequently one finds two principal types of university participation. On the one hand, and for want of a better term, it could be called the European system in which university research is concentrated on problems of a basic or fundamental nature. On the other hand, attempts have been made to transfer the U.S. Land Grant College System in which the University undertakes not only basic but also applied research and, in addition, is associated with the extension process.

The main criticism levelled at the first of these two systems, which posed considerable restraints on the integration of the universities into the overall national research effort in those countries in which it was adopted, stemmed from the isolationist 'ivory tower' attitude of many faculties. The universities tended to avoid involvement in local affairs. Not only was this detrimental to research in general but it was also a hindrance to the development of the faculties themselves since they were isolated from the realities of national agricultural development.

Although the U.S. Land Grant College system has many advantages it also has not provided the perfect answer in many of the countries in which it has been established through aid programmes. Despite the close involvement with the full spectrum of agricultural activities created by this system, or perhaps because of it, there is a tendency for the university to believe that it alone has all the answers. This can lead to conflict with government policies and, at the level of actual research work, to opposing courses being pursued toward the solution of the same problem. Further, too close an involvement in the day-to-day processes of agriculture has been criticised as leading to loss of academic freedom and lowering of academic standards. Nevertheless, if governments are supporting universities for the purpose of conducting applied agricultural research then they have a right to involvement in both the planning and conduct of the research. Equally, however, the inalienable sovereignty of universities in the conduct of academic affairs must be recognised.

A suitable compromise seems to have been achieved in Northern Nigeria where a large government research department has been incorporated into a new university as the 'Institute for Agricultural Research'. Most of the constraints outlined above have thus been ironed out, and the system appears to comprise the best aspects of both systems B and D. It should be noted however that the conduct of extension has been finally left with the Ministry of Agriculture although the university has, with some difficulty, been forced to take over middle-level teaching for the extension services. The system appears to be working extremely well in practice and furnishes an interesting pattern which should be watched.

The Private Sector

Research in the private sector is, as a rule, so specialised as not to impinge too closely on the establishment of national systems. However, in two specific fields it is possible for private sector research to create considerable difficulties for a national system. The first relates to commodity research carried out by the industry in respect of major export crops such as tea, rubber, etc. In many instances such research is financed entirely by the industry, often a foreign owned one, with little or no government control or intervention. Thus government has little control in the organisation of research on what may be one of the country's staple exports and revenue earners. This dichotomy of research in countries with strongly established traditional export crops is, however, gradually being overcome and governments are paying more attention to the nature of and support for research in such crops. Where National Agricultural Research Councils exist, commodity stations are becoming represented and the gradual long-term process of integration of research services is being implemented. Perhaps the most important difficulty created by commodity stations, and to a greater degree by completely independent private industrial research organisations, is their ability in general to establish terms and conditions of service infinitely superior to those offered by government. This creates a disturbing competition for the best research staff in a situation of limited availability. Failing complete and often undersirable 'nationalisation' of all research efforts the solution would appear to lie in the goodwill of all concerned to

reach an acceptable agreement on the setting of grades and salaries and on undertaking not to 'poach' one anothers' staff. This, of course, cannot be relied upon in all cases. The problem is overcome to a large degree when a ministry's research division or institute can have its own conditions of service designed to meet the needs of research staff.

More and more Asian countries have recognised in recent years the need to strengthen and rationalise their national research systems. Since 1955, India, Pakistan, Malaysia, Indonesia, Taiwan and Korea have conducted reviews of their agricultural research systems, usually with external assistance.

It would seem appropriate to close the institutional section of this paper with the recommendations of FAO's research sub-panel regarding an ideal type of infrastructure for the implementation of agricultural research:

'The Sub-panel,

Considering that in developing countries the organisational structure of agricultural research should be designed to facilitate obtaining immediate results and to make use of resources available, and

Recognising the importance of an inter-disciplinary approach to agricultural research

Recommended

that implementation of the agricultural research programme be conducted through a limited number of multi-disciplinary research stations and associated experimental centres, organised on both a disciplinary and commodity basis, located in the different environmental areas of the country of major social and economic importance

that a central agricultural research station be established which would not only serve as the administrative and technical headquarters for implementation of the research programme, but would conduct all research which does not need to be located in other areas of the country and would provide support to the sub-stations through specialised facilities and by making available specialists as required that the organisation and administration of research be such that research staff work together on an inter-disciplinary basis in accordance with the priorities of the research programme, but that they be able to pursue investigations of their own choosing as promising opportunities for research arise.'

RESOURCES FOR RESEARCH

Turning to the question of resources, restraints are imposed in two major components — financial and human resources.

Financial considerations

The allocation of national funds to research in general and agricultural research in particular is inevitably the result of a political decision and must clearly depend to a very great extent on the right climate of opinion prevailing with regard to the relative importance of scientific research against other national needs such as

education, defence, social programmes, etc. In some cases national prestige is allowed to weigh strongly in the favour of research, but the support for research in agriculture, often comes off a poor second best in competition with other scientific and industrial research organisations, even though agriculture is the main stay of the national economy.

If the highly favourable cost/return figures for some agricultural research, cited by Moseman at 300 — 700% annually in respect of the improved wheat and maize programmes, were to be considered in the same way that some major commercial industries consider the cost/benefit of research there is little doubt that we in agricultural research would never again need to plumb the bottom of the barrel for a $500 microscope.

Unfortunately it is extremely difficult for *quantitive* evaluations of expenditure priorities to be undertaken in the absence of startling figures such as those above, as the alternative expenditure headings are strictly non-commensurate. Further, by its very nature, research requires its funding *in advance*, very often many years in advance, of highly rewarding field applications.

We believe that a practical proposal to assist governments in solving the problems of 'how much' and 'when' may be embodied in the United Nations World Plan of Action for the Application of Science and Technology to Development. This embodies some research and development targets based on the Pearson Report, FAO's own calculations for the second Development Decade, and the report of the UN consultants to the Advisory Committee on the Application of Science and Technology. Lack of really comprehensive data on research expenditure imposes difficulties in checking the consistency of these figures but it will be seen that the growth in the *proportion* of proposed research expenditure to the total budget for agriculture greatly exceeds the growth proposed for total agricultural spending. It is fervently hoped that governments do recognise the need for increased research activity and that both national and technical assistance efforts will be increased, to make these targets attainable.

Global Model	1970	1975	1980
Public budget for agriculture (as % of GDP)	1.1	1.2	1.3
Research and development (as % of public budget for agriculture)	6	7	10

Given a total research expenditure, its allocation to the various contenders for a share raises perhaps the most serious difficulties of all. As priorities have to be established at four different levels (national, ministerial, departmental and provincial) it is imperative that a free flow of ideas and information should exist between all four. In order to assist countries in this process, FAO is currently preparing guidelines outlining the type of priorities to be considered and the criteria to be utilised at each stage. Briefly they are:

(1) Priorities within the national budget for scientific research in general and agricultural research in particular

(2) Priorities for agricultural research in different fields of production, utilising such criteria as the percentage of gross national product, industries of direct interest to farmers, growth potential, contribution to overall trade balance, etc.

(3) Priorities between different types of research, in particular long term, basic and applied

(4) Priorities within disciplines and between projects in applied research.

Two categories of research may be recognised also, and the importance of having economists closely associated with decision-making on at least the first of them is evident. They are (a) research to meet future needs following from changes in cropping or production arising from economic development plans, and (b) research into the farmers' immediate production problems — generally of an immediate applied nature.

It is well known that a great deal of research work in both categories is of an ad hoc nature, often un-coordinated and unfinished. We believe that the establishment of clearly defined bodies charged with the appraisal of research priorities is a *sine qua non* for the most economic utilisation of scanty resources. Aware of the need for different criteria to be considered in the different categories of decision making, FAO's research sub-panel reviewed the nature and composition of the bodies which should be responsible for such decisions at each level.

First stage decisions, mainly political in nature, must of necessity be taken at ministerial level, ministries of agriculture, development, natural resources and research, as appropriate. An advisory body or bodies, covering both technical and economic considerations, should be established to advise ministries on research decisions. All too often non-technical administrators alone are charged with disbursement of funds for technical research.

Recognising the need for the farming community to be represented in decision making on research programmes, it was agreed that the participation of farmers, as representatives of farmers groups and organisations, should be at as high a level as possible in order to avoid any suggestion of 'dictation' to farmers and to ensure the essential two-way flow of information on both problems and their solutions. Thus, assuming that second stage decisions will be taken in most countries at the ministry of agriculture level, it is the agricultural research council or similar body of the ministry which should include farmers' representatives. The creation of such a body is regarded as absolutely essential and has been recommended by most authorities.

Third stage decisions would normally be taken by national and regional research institutes and foundations and by ministries which have been allocated central funds for work in specific broad fields. At this level the members of the decision taking body would be mainly professional research directors and team leaders to which could be added representatives of the extension services, agro-industry and farmers, for discussion on problems of regional or district interest.

Finally, fourth stage decisions would be the responsibility of particular research stations or institutes and would be made mainly by scientists.

At the level of the individual research station or institute there are often considerable restraints imposed by budgetary procedures. All too often the needs

of accounting impose rigid sub-heads to expenditure, thus showing fictitious savings when transfers could perhaps have saved a research project abandoned through insufficient funds. More important is the fact that budgeting on a varietal basis, according to disciplines, imposes strong restraints on sound multi-disciplinary team work. Similarly the inability to carry funds over from year to year can impose serious limitations on particular long term research projects. Inflexibility in annual expenditures is also a serious impediment to research planning. Research is a field the dynamics of which call for the most flexible approach possible, not only to keep up with the pace of new developments and discovery, but also to enable emergencies to be met and to permit prompt recruitment of staff and application of resources as needs and opportunities require. Programme budgeting in research is highly desirable and many of the more enlightened research organisations are now employing this approach.

Human Resources

The human resource element in establishing a national research capability is perhaps the restraint which has received most attention in recent years. In general attention has been directed to the shortage of trained manpower in the developing countries as the major limiting factor to the required 'take-off, in agricultural development. Tremendous efforts have been put into the training of agricultural technicians but insufficient attention has been given to the training of 'research workers' to the right levels. Even where adequate training is given, often through post graduate training overseas, many potentially good research workers are lost via the 'brain drain', when trained personnel wish to remain in the more developed countries (frequently those in which they were trained). All too often trained research personnel are required to undertake routine administrative responsibilities on return to their home country, or to take on extension or other operational duties. A real desire to work in a sophisticated research environment, with up to date apparatus and under the direction of acknowledged authorities, the wish for equal status and emoluments with other professionally trained personnel and on an international basis, and last, but by no means least, greater economic security are factors in retention of research workers in their home countries.

Recognising the above basic needs of an individual, and examining the situation prevailing in many developing countries, indicates clearly the restraining effects on research development of indequate attention to the personnel sector. Too much reliance has been placed by many developing countries on bi-lateral and international technical assistance in the training of men to the post graduate level. The supply of agricultural graduates is improving rapidly but until more attention is given to the development of post graduate facilities in the developing nations, allowing graduates to work out their theses on problems of *local* importance, the necessary indentification of a man with his own country's problems cannot be expected to be fully achieved.

Recognising that an effective research worker (often described as a man who through a true sense of vocational dedication has selected that way of life) represents a sound investment from a human resources viewpoint, it is strange that so many countries still refuse to recognise the need for the type of support required to attract and hold researchers. This is particularly true in the civil services of most developing countries. It is only relatively recently that several more highly developed countries have established separate 'Scientific Services' with different statutes and scales of emoluments. FAO is currently working on a publication on the general subject of

conditions of service in research which will take into account a number of factors which have been raised as potential obstacles to recruitment and retention.

Most important is the need for sufficient freedom from normal civil service procedures to permit an atmosphere for creative thinking and innovation. Concomitantly with the above, a salary scale giving parity with other professions (medical, legal, etc.) and which does not depend on seniority for promotion, but rather relies on scientific output and does not necessitate undertaking administrative responsibility for advancements.

The opportunity must be accorded research workers to participate in the planning and preparing of research within broadly defined national goals. Identification with national needs can be a tremendous stimulus but is frequently denied in an atmosphere of rigid administrative direction.

In-service training opportunities, refresher courses, a sabbatical year, study travel, participation in seminars, etc., are other factors requiring very careful consideration in the establishment of satisfactory terms of employment. These all too frequently are not accorded to the research worker or are available only to the most senior personnel.

The training and supply of intermediate level technicians (laboratory and field assistants) requires more attention in many countries of the region. Their absence not only slows down research output tremendously, but also the fact that a research worker has often to do his own routine recording of data, etc. is another factor leading to dissatisfaction of scientists. At FAO's Regional Conference last year a strong recommendation was made to all member governments to take urgent steps to fill the intermediate cadres. This cannot be too often reiterated.

Last, but by no means least, is the question of research direction. Little or no attention is given to formal training in research management and the question of whether, and to what extent, research should be managed by research workers with administrative training, or by administrators with a veneer of technical knowledge, causes problems for most countries. In general it seems advisable to seek administrative ability in research workers.

Material Resources

Material restraints to research can frequently be ascribed to an incorrect or misguided allocation of available funds. Nevertheless there are other limitations such as the selection and siting of research establishments. There are countries whose research stations are so remotely situated, and in particular isolated from newly established universities and central research institutes, as to render them virtually ineffective through difficulties in staffing. We all know of 'one-man' stations and I think all will agree on the need for centralisation for multi-disciplinary team work. Rubbing shoulders with other research workers from other disciplines is a stimulus to good work which cannot be too heavily stressed. The failure to set up field stations with adequate and suitable land areas makes it impossible to conduct sound field programmes. We are also aware of 'white elephant' stations — modern buildings filled with sophisticated equipment but either not staffed with capable scientists or under-staffed. Often these result from political decisions which direct the setting up of research stations in poorly suited or isolated locations. The rational allocation of material resources requires as much clear-thinking as the rational allocation of funds, and at similar levels.

As much of the material resources, particularly equipment, stems from outside aid it seems logical to seek the assistance of the donor in determining the most apposite siting and utilisation of that equipment. Unfortunately, this is not always done and many donors supply equipment without following through on its subsequent utilisation. Countries themselves must also be wary of acceding too readily to the requests of young research workers for advanced and difficult to maintain equipment when something more simple would serve. To strike a suitable balance between what is economically feasible or necessary, and what a research worker demands, is one of the most trying problems of research directors.

It will be noted that, in general terms, the commonly existing restraints in the human sector are products of the organisational and administrative system under which research is conducted. Similarly, restraints rated as financial can well stem either from the politico-social sector or from the organisational sector. Material restraints, being immediately dependent upon financial restraints, can again be traced back to national policies. As stated at the outset so many of the restraints besetting the establishment of a national research capability are inter-dependent and *only soluble at the highest level through a research advisory body comprising all sectors of the industry and national planning authorities.*

This review is by no means exhaustive. As Dr. Moseman has stated, so many of the factors imposing restraints on research are minute, but it is believed that major restraints have been noted and that adequate material for discussion has been supplied.

Part II

National Crop Improvement Research Programmes

The All-India Coordinated Rice Improvement Project

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The advantages of a crop as the nucleus of research organisation have been well recognised. Likewise, the value of multi-locational, multi-disciplined coordinated research in achieving quick and effective progress in crop improvement has been well demonstrated. In countries with wide variation in agro-climatic conditions and where research organisations are administered by different agencies, the coordinated approach is particularly relevant since it mobilises human resources and location-specific advantages without gross administrative changes in the institutions under different agencies. It is, therefore, not surprising that the Indian Council of Agricultural Research (ICAR) places a high priority on projects such as the All-India Coordinated Rice Improvement Project (AICRIP) initiated in 1965.

EARLY HISTORY

The establishment of the Central Rice Research Institute (CRRI) at Cuttack in 1946 was the first major federal input in rice research. A second major contribution of the Government of India was the identification of main centres and regional centres for rice research in different states. These centres received support by way of personnel and equipment during the Third Five Year Plan.

The AICRIP which was established under the Fourth Five Year Plan differs from earlier programmes by providing 100% assistance of senior research personnel (without stipulation of matching funds from the recipient state research centres) and some equipment at the more important rice research centres. The change in magnitude and form of assistance from the Government of India was guided by the urgency for increasing rice production, and reflects the new strategy of the evolution and spread of dwarf, better management-responsive and high-yielding rice varieties.

While the CRRI remains the major national rice research centre the AICRIP is responsible for operation of a common national programme, integrating the 'isolated' research efforts of over 100 rice experiment stations throughout the country.

The Scientists' Panel to the Union Minister of Agriculture recommended the initiation of the AICRIP. Although the project came into existence in April, 1965, with the National Coordinating Centre at Rajendranagar, Hyderabad, field facilities could not be developed for another year. The formal assistance to the research

centres came into effect only in 1969 with the approval of the Fourth Five Year Plan. A scientific Advisory Committee, with Dr. K. Ramaiah as Chairman, was constituted to guide the AICRIP in setting research priorities, utilising existing institutions.

The main strategy of the AICRIP is to utilise existing personnel and facilities to maximise technological output. The challenges and problems that were obvious with the introduction of the first dwarf rice variety, Taichung Native 1, were foremost in consideration. In order to cater to diverse agro-climatic regions of the country and meet the wide variation in consumer preferences, it was considered essential to undertake a massive hybridisation programme between local varieties and the dwarf *indicas*. The All-India Rice Workshop of November 1965 drew up a programme of hybridisation involving major rice research centres in the country and agreed to implement it cooperatively. It is a tribute to the dedication and industry of co-operating scientists that this programme paid off in the release of two varieties, Jaya and Padma, in 1968 — within three years after its initiation. The release of the high-yielding variety Jaya in a record time of 3 years is a testimony to the rapid assessment provided by the AICRIP testing programmes.

The programme of the AICRIP has enjoyed full support of The International Rice Research Institute from its very inception. The IRRI made available promising lines from its breeding nurseries, numbering 48 in **rabi* 1965, 165 in *kharif* 1965, and 300 in *rabi* 1966. These materials provided the initial new dwarf plant germ plasm and accelerated the breeding programme in India. With the development of local programmes, the introduction of breeding materials from the IRRI is now limited to some special types. Greater reliance is placed upon materials developed within the country, yet utilising the best selections developed anywhere in the world.

ORGANISATION

The National Coordinating Centre at Hyderabad is headed by a Project Coordinator. The Rockefeller Foundation designated a senior scientist as Joint Coordinator and provided junior staff on a training basis together with equipment not readily available in India. A contract between the USAID, IRRI and ICAR (1967) provided support for 4 senior foreign scientists, through the IRRI, for some Indian scientists, and for equipment to step up research at the coordinating centre.

The rice growing area of the country has been organised into 7 zones, taking into account the agro-climatic differences. The major research centre in each zone is identified as the Zonal Centre. The senior scientist at the Zonal Centre is designated as the Zonal Co-ordinator. He is under the local administration of either the Agricultural University or the State Department of Agriculture and is technically responsible for the programme of the AICRIP in the zone. The main research centres in the states are recognised as Regional Centres. Twelve major rice growing states are identified by one regional centre each. The states where both zonal and regional centres are located include Uttar Pradesh, Orissa, Andhra Pradesh and Tamil Nadu. Three testing centres were provided at Upper Shillong (Meghalaya), Kalimpong (West Bengal) and Imphal (Manipur), *(Appendix I)*.

Since crop improvement involves a multi-disciplined approach, the ICAR provided all zonal and regional centres with two scientists (one senior and one junior) in each of the disciplines of breeding, agronomy, pathology and entomology. The only difference in assistance between zonal and regional centres is the identification of a Zonal Coordinator in the former. The testing centres are provided with junior

**Rabi* is the dry season (January-June); and *kharif* is the monsoon season (July-December).

staff in disciplines of greater significance at the respective locations. Special staff in bacteriology and virology have been provided at the Indian Agricultural Research Institute. Warangal, in Andhra Pradesh, is a location consistently subject to heavy depradation by rice gall midge and hence this centre is designated as the National Centre of rice gall midge investigations and is provided with a senior entomologist and a junior ecologist.

Provisions have also been made for greenhouses, field equipment, seed storage buildings and limited operational funds over and above those existing at the zonal, regional and testing centres. The additional contribution from the ICAR during the fourth plan period (1969–74) is about Rs. 16 million.

TESTING PROGRAMME

The underlying objective of the AICRIP is to promote a spirit of involvement by all rice scientists of the country in a common programme. The provision of extra personnel and facilities is merely an augmentation of inputs. The testing programme of AICRIP is not limited to the 24 research centres receiving ICAR assistance, but includes 108 research stations throughout the country *(Table 1)*. Two central institutes, the IARI and the CRRI, nine agricultural universities, and several state departments of agriculture are involved in the programme of multi-location testing. Rice workers from most of the cooperating centres participate in two AICRIP workshops each year to review the research results of the preceding season and to draw up the programme for the following season.

TABLE 1. RICE RESEARCH CENTRES INVOLVED IN THE AICRIP TESTING PROGRAMME, KHARIF 1970

AICRIP Zone No.*	Research Centres				Centres not receiving direct assistance rom the ICAR			
	Zonal	Regional	Others	Total	Breeding	Agro.	Path.	Ent.
I	1	2	4	7	4	4	1	–
II	1	–	4	5	4	1	–	–
III	1	1	17	19	15	4		–
IV	1	1	12	14	11	9	2	1
V	1	2	11	14	11	7	–	1
VI	1	4	36	41	25	7	8	2
VII	1	2	5	8	5	–	1	–
Total	7	12	89	108				

* See Appendix I

The earliest stage of variety testing is the Initial Evaluation Trial (IET). These trials include material developed anywhere in the country together with the introductions from the IRRI. The next stage is the Preliminary Variety Trial (PVT), which is composed of superior performers in the IET. The final stage is the Uniform Variety Trial (UVT), in which performance is judged not only for yield, but also for nitrogen responsiveness. All these trials are further divided into three groups (UVT–1, UVT–2 and UVT–3, etc. with varieties of growth duration 100–120 days,

120–140 days and 140–160 days). The trials — IET, PVT and UVT — include a progressively smaller number of entries and are more extensively tested. With the evolution of selections with superior grain type, a separate trial equivalent to the PVT stage of testing, with these slender grain varieties (SGVT) was constituted in 1968.

The locations are limited in rabi due to seasonal conditions as well as lack of irrigation facilities *(Appendix II)*. Locations chosen to sample known diversities in climatic and soil conditions are under constant review and exhibit a steady increase from 1966–1970.

The magnitude of the variety testing programme is evident from the materials that were in multi-location testing which provided the basis for release of varieties *(Appendix III)*. During the period 1966–1970, nearly 1500, 300 150 and 100 new materials generated all over the country were tested in the Initial, Preliminary, Slender Grain and Uniform Variety Trials. As a result of this programme, 14 improved varieties (including 3 introductions) were released for cultivation in the country. Released varieties include attributes such as high yield (Jaya, Vijaya, IR8, Pankaj), earliness (Cauvery, Bala, Kanchi, Krishna, Padma), resistance to pests and diseases (Ratna and IR20) and good grain quality (Ratna, Sabarmati, Jamuna, Krishna, Vijaya, IR20, Jagannath). Apart from the 14 varieties released by the Central Variety Release Committee (CVRC), six varieties have been released by cooperating states, for cultivation in specific localities. These are Hamsa for the Telangana region in Andhra Pradesh; Annapoorna for parts of Kerala; Sarjoo 49 (introduced from Taiwan through the IRRI) for parts of Uttar Pradesh; Suma and Kusuma for parts of Mysore; and Karuna for *Kuruvai* season of Tanjavur delta in Tamil Nadu *(Table 2)*.

More recently, adaptive testing of released varieties was undertaken on farmers' fields. The extension agencies are more closely involved in these trials. Tests referred to as District Level Trials confirmed the superior performance of Jaya over IR8 in Punjab and Haryana states and led to the identification of the early maturing variety, Karuna, which is suitable for the Tanjavur delta of Tamil Nadu.

ADAPTABILITY OF VARIETIES

The major restriction to wide adaptability of rice varieties is photosensitivity. Since current breeding programmes are mostly geared to produce photoinsensitive types, this is no problem and accounts for the wide adaptability of varieties like IR8 from 10°N — 25°N latitude. The performance of photoinsensitive varieties is, however, greatly influenced by the length of growing season, which is short in many rainfed areas and in areas commanded by minor irrigation. In some cases, an extended monsoon season and poor water control lead to a preference for long duration varieties for convenience in harvesting. Yet in other situations the economics of the crop to follow rice are so favourable that an early variety is preferred, even at a minor sacrifice in yield. These considerations emphasise the need to evolve varieties with maturity ranging from 90 to 170 days and yet retaining high yielding ability.

Yield stability of dwarf rice varieties is strikingly good under various levels of management. As a group, these varieties give higher yields than the local tall varieties at all levels of management *(Appendix IV)*. A general indication is that high yield potential is more easily attainable in varieties of medium duration (Jaya-IR8, 130–140 days) than in varieties earlier and later to this group.

TABLE 2. DWARF RICE VARIETIES RELEASED FOR CULTIVATION IN INDIA, 1966–1970

Factors favouring acceptance	Variety	Adaptability	Limitations to wider acceptance**
Earliness	Cauvery	Multiple cropped-transplanted	Weak straw
	Bala	Rainfed, uplands	Low tillering; poor grain type
	Kanchi	Multiple cropping	—
	Karuna	Multiple cropping (Tamil Nadu *Kuruvai* season)	Susceptibility to BLB
	Annapoorna	First, crop, Kerala	Red kernels
	Hamsa †	Rabi, Telangana region of A.P.	Low yield
	Krishna †	Multiple cropping	—
	Padma	Summer crop, East India	Susceptibility to diseases
	Sarjoo 49	East U.P.	Poor grain type
	Suma †	Mysore	Low yield
	Kasuma †	Mysore	Low yield
Mid-duration and high yield	Jaya	General cultivation	Poor grain type
	Vijaya*	General cultivation	—
	IR8	General cultivation	Poor grain type
Long duration	Pankaj	Coastal A.P., Orissa and second crop of Tamil Nadu	—
	Jagannath †	Coastal A.P., Orissa and second crop of Tamil Nadu	Susceptibility to blast
Good grain	Ratna*	West U.P. and Punjab	—
	Sabarmati	North West Plains	—
	Jamuna	North West Plains	—
	IR20*	East India	Weak straw

* Resistant to green leaf hoppers, Vijaya being the best.

** All are susceptible to rice gall midge and bacterial leaf blight. IR20 is relatively less susceptible to bacterial leaf blight.

† Good grain type.

There are striking differences between varieties in susceptibility to diseases and pests. Regional and seasonal variation in distribution of pests and diseases must be taken into account in extending the utility of a variety. For example, all the dwarf rice varieties thus far released are highly susceptible to gall midge; yet 4.4 million hectares were planted with these varieties in kharif 1970. All the dwarf varieties thus far released are susceptible to varying degrees to bacterial leaf blight. This disease is far less severe in the dry season (rabi) when any of the dwarfs can be grown with minimal risk. Minor differences in suceptibility can also guide the choice of dwarf varieties for the wet (kharif) season. The intensity of the disease can be reduced somewhat by judicious nitrogen management.

An essential feature of the testing programme is the identification of adaptational deficiencies of varieties prior to their release for cultivation. This is accomplished by the large number of pest and disease evaluation nurseries, chosen to represent areas with heavy pest damage. All materials in variety trials are included in these screening tests to assess the merits of the varieties, guide decisions on release, and to identify 'trouble-free' regions for the variety *(Table 3)*.

TABLE 3. PROGRAMME OF PEST AND DISEASE SCREENING — AICRIP (1968–70)

Pest/Disease	1968		1969		1970	
	Entries	Locations	Entries	Locations	Entries	Locations
Stem borer	891	6	828	8	483	11
Gall midge	1149	5	7809	7	1438	9
Leafhopper	800	3	731	6	665	7
Blast	800	13	2283	11	1954	13
Bacterial leaf blight	852	5	3120	7	1570	9
Helminthosporium	800	3	740	6	640	7
Tungro	550	1	680	1	3575	1

The varieties IR8 and Jaya, which are resistant to blast and tungro disease, maintained good performance in blast-endemic southern Andhra Pradesh and withstood the RTV epidemic of 1969 in North-East India. These tests also have revealed several new sources of resistance to pests and diseases *(Table 4)*. For example, the variety BJ 1 is by far the best known source of resistance to bacterial leaf blight, resistant to several isolates from India as well as from many other Asian countries. The variety Latisail is highly resistant to the virulent race of RTV which was involved in the epidemic of 1969 in North-East India.

BREEDING PROGRAMMES

Grain Type

Utmost attention is being given to incorporating superior grain quality of Indian table varieties into high yielding dwarf plant types. Gratifying success has already been achieved in the released varieties Ratna, Krishna, Sabarmati, and Jamuna; but even so, the yield and quality of these varieties need further improvement.

TABLE 4. NEW SOURCES OF RESISTANCE TO PESTS AND DISEASES, IDENTIFIED IN THE AICRIP SCREENING TESTS.

Pest/Disease	Variety	Source
Stem borer	W 1263*	APAU, Warangal, AP
Gall midge	JBS 446 Desi Bayahunda DNJ 45 ARC No. 5810 Landubbisali and 40 others from Assam	Orissa East Pakistan Assam
Green leafhopper	Eswarakora* W 1263* Vijaya	APAU, Warangal, AP APAU, Warangal, AP CRRI, Orissa
Blast	ARC No. 5774 ARC No. 5993 Mikiri Ahu	Assam Assam
Bacterial leaf blight	BJ 1 Malagkit Sungsung	West Bengal Philippines
Tungro	Latisail Kataribhog Pankhari 203 Kamod 253 Ambemohar 102 Ambemohar 159	West Bengal West Bengal Gujarat Maharashtra Maharashtra Maharashtra

* Earlier identified as highly resistant to rice gall midge

Maturity

Dwarf, high yielding varieties ranging in maturity from 90–170 days are being developed. By far the most promising selections in the early group originate from the tall varieties (TKM 6, Co 29 and N 22) and those of mid-duration from the crosses involving T 141, T 90 and GEB 24. Varieties of later maturity need not necessarily be photosensitive.

Gall Midge Resistance

Infestation by the rice gall midge transforms the growing point into an onion-leaf like structure, called silver shoot, and renders the shoot unproductive. Ancillary symptoms are profuse tillering and stunted growth. This pest, which occurs in parts of South India, Ceylon, Thailand, Malaysia and Indonesia, takes a severe toll on rice and is extremely difficult and expensive to control with chemicals. Excellent sources of resistance have been found by research at the CRRI, APAU and at the AICRIP Coordinating Centre. A group of tall selections developed from the cross Eswarakora x MTU 15 shows near immunity to this pest and has recorded fair yields under conditions when susceptible varieties were completely damaged. Dwarf gall midge resistant varieties are being developed and about 100 selections are in advanced stages of testing.

Resistance to Green Leafhoppers

Among the released varieties, Vijaya shows a high level of resistance to green leafhoppers while Jaya, IR8 and IR20 are moderately resistant. The gall midge resistant variety Eswarakora and tungro resistant variety Latisail are highly resistant to green leafhoppers. Even after feeding for 10 days on their hosts the leafhoppers

do not produce a decline in the condition of the plants. Dwarf selections originating from crosses with Latisail and Eswarakora are being screened for resistance to this pest.

In order to estimate losses in yield from insect damage, field experiments were laid out by the AICRIP in different test locations with two treatments, one completely protected by Diazinon granular application every fortnight and the other under completely unprotected conditions. The yield gains in some locations was phenomenal for the susceptible variety IR8 *(Appendix V)*. Under heavy infestation even costly granular insecticides would, therefore, be worthwhile. With the resistant variety W 1263, which is nearly immune to rice gall midge and moderately resistant to stem borer and leafhoppers, the yield gains from complete protection are marginal *(Appendix V)*. Breeding for insect resistance in rice, which looked not so hopeful some years ago, is now one of the major fields of activity at many research centres.

Blast

Rice blast disease is very serious in some parts of India. The pathogen is differentiated into several races, which are not stable, thereby increasing the complexity of breeding resistant varieties. Good sources of resistance are known, consistently high disease pressure is attainable in some locations in India and simple techniques for mass screening are available. Many of the released varieties are at least moderately resistant. Jaya, Vijaya and IR8 are highly resistant while Jagannath is susceptible. Screening tests for blast, conducted between 1968–1969 at Ponnamphet, where the disease pressure is very high, identified 28 highly resistant dwarf selections. The prospects are promising for identifying blast resistant, high yielding varieties for this region.

Bacterial Leaf Blight

Emphasis on this disease justifiably increased with the spread of dwarf varieties, which are usually grown under higher nitrogen levels, conducive to increased disease incidence. The disease spreads rapidly under the conditions of high temperature and humidity which prevail in the monsoon season all over India. Chemical control measures are either undependable or prohibitively expensive. Host plant resistance is not as good as for blast. Isolates of the pathogen collected from different regions exhibit differential disease reactions on the same variety, indicating pathogenic variation. So far, no variety has been identified which gives consistent resistant reaction to all isolates of the pathogen. While progress in incorporating a high level of resistance to diverse isolates appears remote, there are minor differences in field reaction which can be exploited immediately. The level of resistance of two good donors, BJ 1 and Sigadis, is being transferred to dwarf plant types.

Rice Tungro Virus

The existence of this disease in India was questionable as late as 1967 but critical studies at the Coordinating Centre established its presence. Research on host plant resistance identified 6 resistant varieties, one of which, Pankhari 203, was also known to be resistant on the basis of research at the IRRI. Within two years (*kharif* 1969) after the identification of the disease an epiphytotic of RTV broke out in Northeast India. Scientists at the AICRIP Coordinating Centre established that RTV was the major cause for the 'mysterious leaf yellowing' and concluded that the strain involved was more virulent than the ones encountered earlier. Varieties resistant to RTV_1 (the common strain) were screened for reaction to RTV_2 (the more virulent strain). From large populations of F_2 plants from the cross, IR8 x Latisail

tested for resistance in *rabi* and *kharif* 1970 twenty selections which combine good plant type with resistance have been identified. This was only two seasons after discovery of the problem!

Problems which hitherto were minor may become serious with the spread of the dwarf varieties and associated intensive crop management. Not long ago the sucking insects, leaf and planthoppers, were regarded as minor pests. The micro-climate in the dense stands of a well-managed dwarf variety is so different from lighter stands of relatively poorly managed tall varieties that these pests are now a matter of serious concern, not only for direct feeding damage but also for the diseases they transmit. Top canopy feeders like leaf roller, leaf minor and cut worms are becoming increasingly menacing to well-managed crops of dwarf rices, even with protection from granular insecticides. Sheath blight, stem rot, Helminthosporium and Cerospora leaf spot diseases need to be monitored and protective research should be intensified to forestall major pest-disease outbreaks. Present research on chemical control and host plant resistance on these diseases and pests is extremely fragmentary.

Summary of breeding objectives

Diversity in agro-climatic conditions in a large country such as India emphasises the need to identify high yielding varieties which mature in 90–170 days. For each maturity group, it is necessary to consider both coarse and fine grain varieties. The latter, in general, are not as high yielding as the former but the consumer preferences for grain types, as reflected in price differential, vary from region to region. Breeding for resistance to three major pests and three major diseases is possible and a feasible objective is to combine multiple resistance to pests and diseases in a single variety. It is, however, not absolutely essential that every variety should possess all the six resistant factors, since simultaneous occurrence of these problems is unlikely. Breeding for disease and pest resistance is the major task for the future, since only 9 out of 25 present varieties possess a satisfactory level of resistance to even a single major pest or disease. The number of resistant varieties in the extremely early group (90–100 days) and extremely late group (150–170 days) is far too limited. Resistance to pests and diseases is relatively poor also in the varieties of 110–130 days duration group thus far released. Future programmes will attempt to cover these deficiencies.

MANAGEMENT FOR HIGH YIELDS

Management is directed toward minimising the disparity between potential and performance of a variety of rice in a given situation. The new factor in the cultivation of dwarf rices — not well understood by farmers traditionally accustomed to the cultivation of tall, poor N-responsive varieties — is the management of fertiliser. Promotion of tillering by shallow planting, thorough incorporation of nitrogen fertilisers, timing of fertiliser application and proper water management — all aimed at promoting tillering in the vegetative stage and maintaining the leaf activity at later stages — are the essential features of good management.

Research on fertiliser practices is mostly centred around determination of methods, optimum rates and times of nitrogen application for different varieties under different soil and climatic conditions. Split applications of nitrogen, with 2–3 topdressings, have produced consistently higher grain yields than when all the nitrogen was applied at planting. The number of topdressings will be greater in lighter soils. In this practice of fertilisation, plant uptake itself is utilised to minimise nitrogen losses, and the efficiency of nitrogen application has been increased by approximately 15–20 per cent. During the early vegetative stage tillering is greater in basal application treatments but this, followed by greater tiller mortality, results in comparable

panicle number in basal-and-split-application treatment. Increased grain yield following split application of nitrogen is attributable to higher panicle weight.

Pest control is an essential part of management. Hitherto, chemical control of internal feeders like stem borers and gall midge has been difficult. With the use of granular insecticides, which operate in a semi-systemic way on larvae and grubs and as fumigants on adults (when applied to paddy water), the control of these pests becomes feasible and dependable. Although these chemicals are costly their usage is economical at infestation loads in excess of 20–25%. Several measures to economise the insecticides are being considered. In the control of host-stage-specific pests like gall midge, a single application of Diazinon together with close spacing is adequate. Critical timing for one single application each for the control of dead hearts and white ears of the rice stem borer is being investigated.

Generally speaking, yields of about 3 tonnes/ha for a poor plant type can be elevated to a higher plateau of about 5 tonnes/ha for varieties with good plant type. Judicious nitrogen management and pest control are likely to raise the yields still further, to 6–8 tonnes/ha. Yields of 8–10 tonnes/ha are greatly dependent on bright sunshine during the pre-flowering and ripening stages. Record yields of over 10 tonnes/ha are attainable occasionally if all factors are favourable but they are not reproduceable with certainty *(Table 5)*.

TABLE 5. RECORD YIELDS OBTAINED WITH DWARF VARIETIES AT THE AICRIP COORDINATING CENTRE, RAJENDRANAGAR (1966-70)

Season	Year	Trial	Variety	Grain yield (kg/ha)
Rabi	1966	PVT	IR8	7753
,,	1968	N-P-K	IR8	11081
,,	1968	UVT	IR8	7628
,,	1968	PVT	Jaya	8168
,,	1969	TAN	IR8	10465
,,	1969	Maximisation trial	IR8	12473
,,	1969	Maximisation trial	Jaya	10787
,,	1969	PVT	IR8	7589
,,	1969	PVT	Jaya	8898
,,	1970	Growth Analysis	IR8	11243
,,	1970	Direct Seeding	Jaya	14800
,,	1970	N and Spacing	IR8	10679
,,	1970	N and Spacing	Jaya	9668
Kharif	1966	PVT-1	IR8	7302
,,	1967	PVT-1	IR8	10504
,,	1967	Age of seedlings	IR8	9170
,,	1968	PVT-2	IR8	6220
,,	1968	IET-2	Jaya	7094
,,	1968	NVT	IR8	8784
,,	1969	UVT-2	IR8	6795
,,	1969	UVT-2	Jaya	6921
,,	1969	Growth analysis	IR8	10925
,,	1969	Growth analysis	Jaya	9350

ACKNOWLEDGEMENTS

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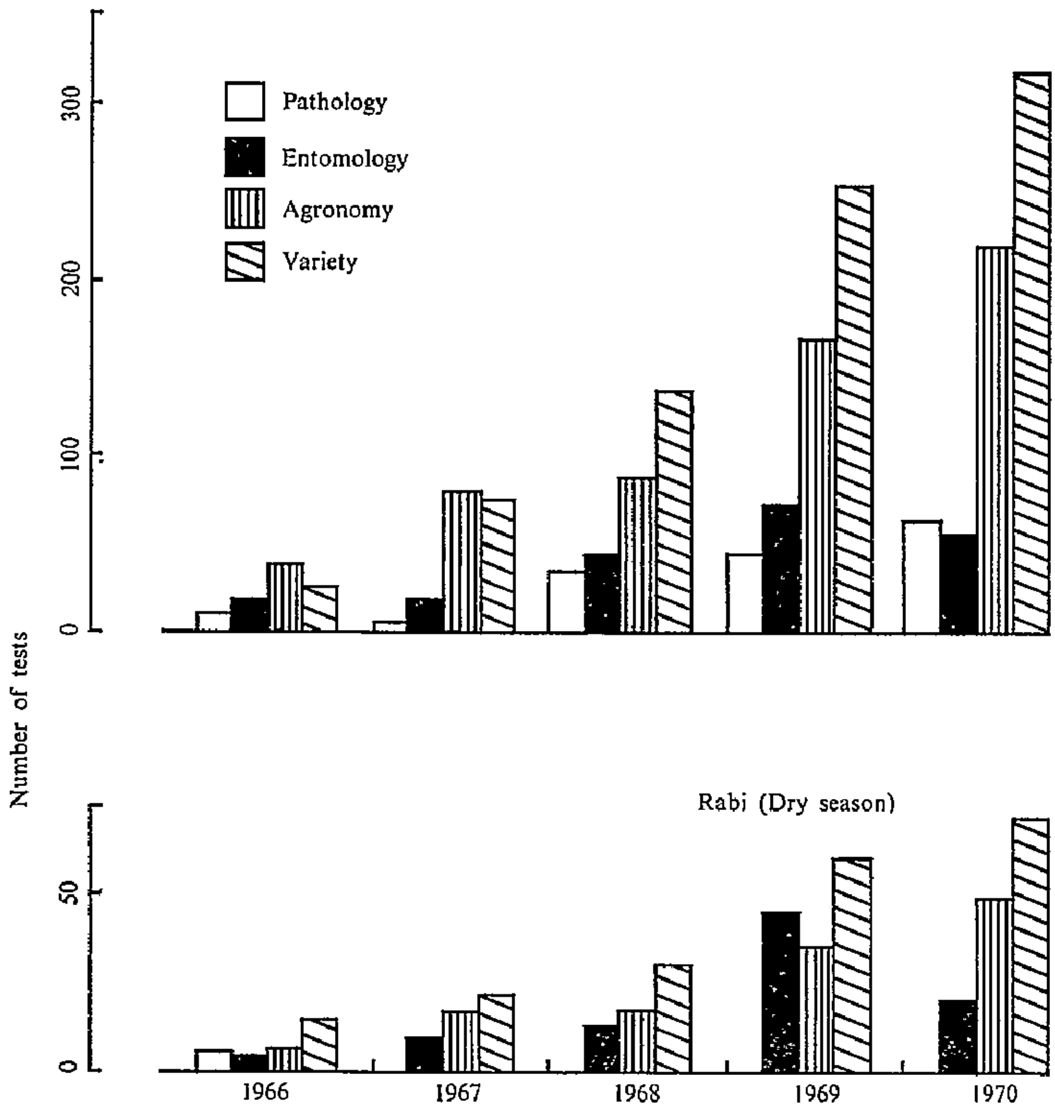
APPENDIX I

RICE RESEARCH STATIONS COOPERATING WITH THE ALL-INDIA COORDINATED RICE IMPROVEMENT PROJECT

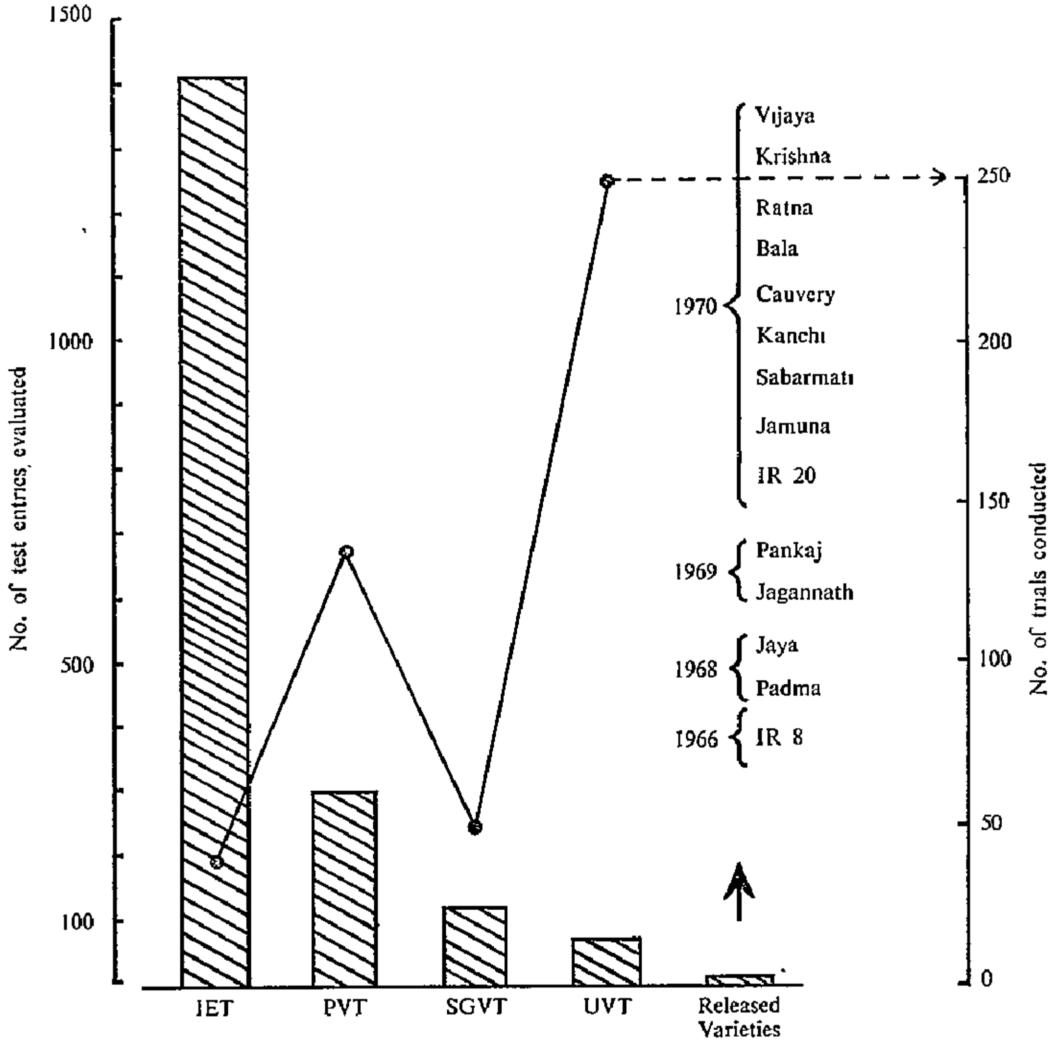
AICRIP Zone No.	Regions of the Country	States Involved	Specific Objectives	Headquarters of the Zone	Regional* Centres	Testing Centres
I	Northern and northeastern hills	Jammu & Kashmir Himachal Pradesh Uttar Pradesh Hills West Bengal Hills Meghalaya, Nagaland	early maturity, cold tolerance and blast resistance	Srinagar	Palampur Majhera	Upper Shillong Kalimpong
II	Northeastern valleys	Assam, Manipur *Tripura*	adaptation to water logged conditions	Jorhat	—	Imphal
III	Northwest plains	Punjab, Haryana Uttar Pradesh Rajasthan	early maturity and drought resistance	Faizabad	Kapurthala	—
IV	Northeast plains	Bihar, West Bengal	pest and disease resistance	Patna	Ranaghat	—
V	Central plains	Orissa, Madhya Pradesh	adaptation to water logged conditions	Cuttack	Sambalpur Raipur	—
VI	Northern peninsula	Andhra Pradesh, Maharashtra, Mysore, Gujarat	wide variation in maturity, cold tolerance and resistance to pests and diseases	Hyderabad	Maruteru Karjat Nawagam Mandya	—
VII	Southern peninsula	Tamil Nadu & Kerala	early maturity and disease resistance	Coimbatore	Aduthurai Pattambi	—

* In addition to regular regional centres, personnel are provided at the Indian Agricultural Research Institute, New Delhi, for rice disease investigations and at Warangal (A.P.) for research on rice gall midge.

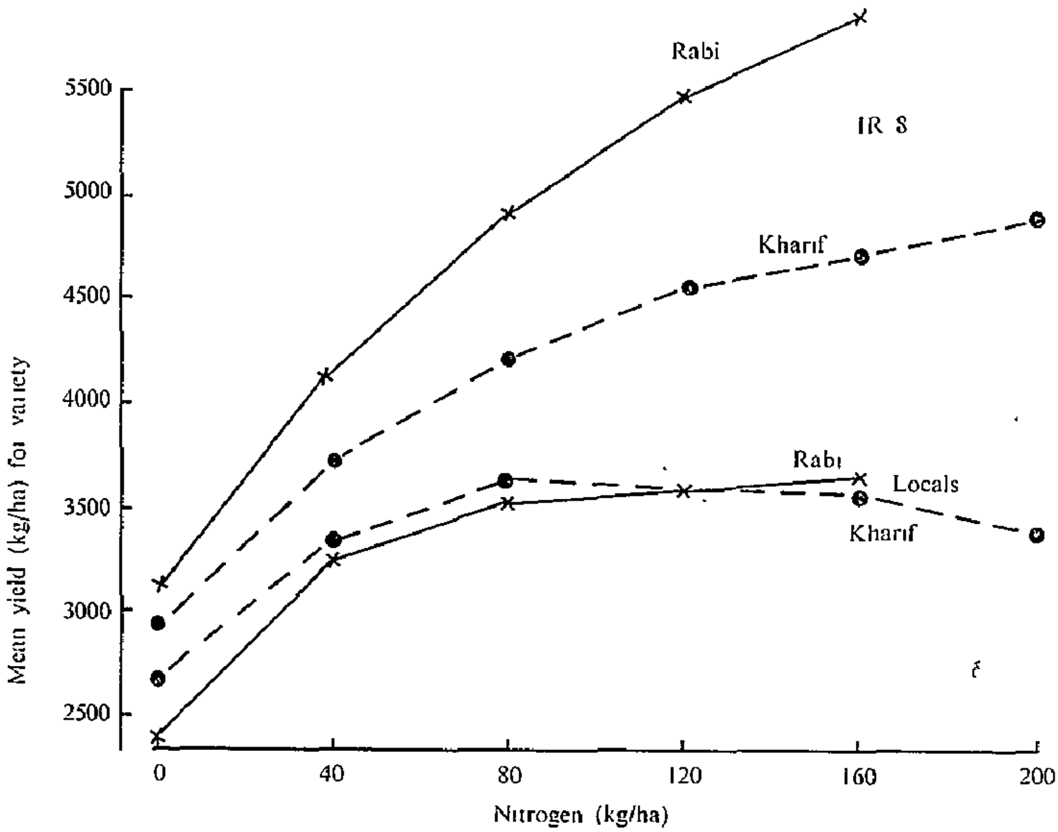
PROGRESS OF THE AICRIP TESTING PROGRAMME



NUMBER OF AICRIP VARIETY TRIALS CONDUCTED IN VARIOUS STAGES OF TESTING, 1966–1970

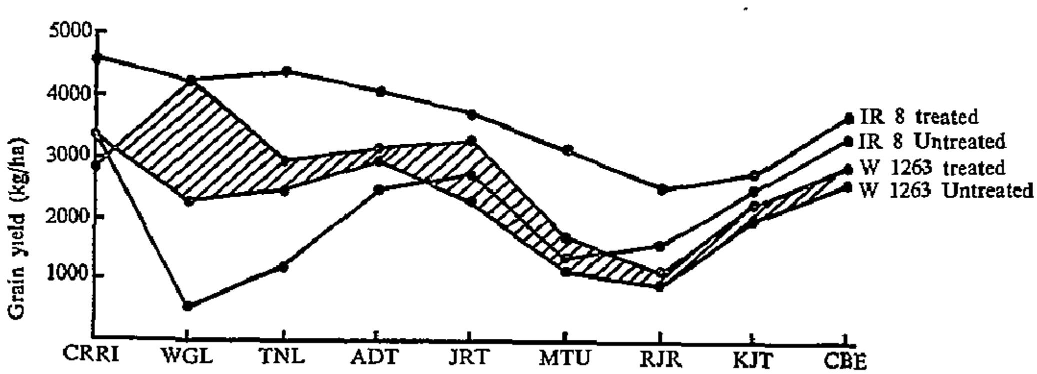


SUMMARY OF N-RESPONSE IN DWARF *INDICAS* AND TALL LOCALS
(3 KHARIF AND 3 RABI SEASONS, AICRIP)



YIELDS OF IR8 UNDER MAXIMUM INSECT PROTECTION AND NO PROTECTION, MAXIMUM PROTECTION TRIAL, KHARIF 1968

YIELDS OF IR8 AND W 1203 UNDER TREATED AND UNTREATED CONDITIONS IN THE MAXIMUM PROTECTION TRIAL, KHARIF 1969



Rice Improvement Research in Thailand

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The rice improvement research system in Thailand was first organised with the establishment in 1916 of the Rangsit Rice Experiment Station near Bangkok. Research activities at the Station and its two branch stations in the Central Plain during the early period were mainly on varietal improvement by selection, soil fertility improvement, and mechanisation. The major achievement in rice improvement research of the station was recognised when new varieties developed by the station won eleven of the twenty prizes, including the top three, in the International Rice Contest held in Regina, Canada in August 1933. Since then the grain character of Pin Kaeow, the first prize variety, has been consistently used as the standard for long-grain Thai rice in rice breeding and in the trade. Because of the limited number of trained personnel, the rice improvement research and extension programme during the early period was confined mostly to the Central Plain Region which is the rice bowl of the country.

Reorganisation and expansion of the rice improvement research system came in 1952 when the Rice Department was established with its scope of work extended to cover the entire country. While varietal improvement has maintained its prominent part in the national rice research programme, research in other major fields has also been gradually strengthened to contribute towards the realisation of higher yield in farmers' fields. Research in various disciplines to solve local technical problems is presently being handled at twenty-one rice experiment stations scattered over the country; they also serve as seed farms, producing foundation and stock seeds of approved varieties for distribution to farmers in different areas. A research committee has been set up to guide and coordinate all research activities within the Department. In addition to the Rice Department some rice research is also being conducted in several agriculturally related agencies and institutions, generally with close cooperation of the Department.

Since the inception of the Rice Department, the objectives of the rice breeding programme have gone through several changes. The widespread occurrence of rice blast disease during the late 1950's, caused primarily by increasing use of chemical fertilisers, showed that many of the recommended varieties selected under the old criteria were no longer useful. This incident prompted the Department to modify the objectives of its rice breeding programme to include varietal resistance

to some major pests and diseases. The standard blast nursery test has been since adopted as a routine practice in rice breeding, and most of the newly released varieties, with only a few exceptions, now possess some degree of resistance to the disease.

Recently there was another very serious menace to the rice crop caused by the yellow orange leaf virus disease, with the green leafhoppers which are also common rice pests themselves, as its vector. A crash research project had to be undertaken by a team of research workers from all relevant disciplines to combat this disease. This resulted in the release of two new resistant varieties which are widely acclaimed by farmers. The disease, however, is still considered the most serious in Thailand at present, and will require continuous intensive research for some time before it will be effectively controlled.

In some areas rice crops frequently and increasingly suffer from infestation by the gall midge. Many years of concerted efforts by both entomologists and breeders will soon produce some resistant varieties as the research work is now in the final stage. Several research projects are currently in progress to develop varieties with resistance against other major pests and diseases such as stem borers, brown planthoppers and bacterial leaf blight.

Because of the existence of very diverse rice growing conditions, particularly with regard to the water regime, there is still the necessity for improved varieties of different plant types — from the modern short erect plants to the typical tall plant types capable of growing in deeper water — which are sensitive and non-sensitive to photoperiods. High yielding potential and high milling and eating quality are basic standards for all new varieties as they have to be approved by a selection board composed of scientists as well as millers before they can be officially released to farmers.

While rice improvement research appears to centre mainly on developing new improved varieties for the farmers, its success is vitally dependent on the research advancement in all relevant scientific disciplines. Thus, current research activities are being strengthened with additional staff and facilities particularly in the fields of crop protection, soil fertility, soil science, chemistry and agronomy, including weed control.

Most of the research work on rice improvement in Thailand so far, and most likely for the foreseeable future, is applied in nature, being aimed towards solving the innumerable production problems of small farmers. These problems are probably quite similar to those of other developing countries of Asia. The results of these coordinated research efforts have greatly benefited Thai farmers and modernised their farming practice. Several new improved rice varieties have been released from time to time to replace the old inferior varieties. These new varieties have higher yield potential and resistance to some major pests and diseases such as blast, yellow orange leaf virus, gall midge and hoppers. The use of fertilisers, pesticides, and herbicides to assure high yield in rice production is being more widely practised by the farmers as more precise information from research results is available to them.

While considerable progress has been made, much still remains to be done in order to sustain satisfactory growth in rice production on a long-term basis. The rice varieties will have to be improved for wider range of tolerance to adverse environmental conditions and resistance to several presently unsolved pests and

diseases. They also need improvement in higher nutritive value and better eating quality. Problems in other scientific disciplines are also numerous. It appears that future problems will become increasingly complicated, thus requiring more advanced and extensive research.

Thailand's rice research achievements, as mentioned above, have been made possible partly through the cooperative efforts and assistance of many foreign governments and international organisations. The Thai research staff has been significantly strengthened by visiting research workers from other countries; simultaneously, a substantial number of Thai staff members have also had opportunities to advance their training and experience abroad through cooperative programmes. Specifically to be cited is the contribution of the IRRI to the overall enhancement of rice improvement research in Thailand. Cooperative work between Thailand and the IRRI has been closely maintained since the establishment of the Institute.

During the early years, scientists from the Institute made periodic visits to Thailand to confer with Thai rice scientists and develop research programmes of mutual interest. Several Thai nationals were sent to the Institute for training in 1962. This attained a maximum in 1963 when 11.6 man years of training were completed. Of the ten Asian countries who have provided the majority of trainees for the IRRI, from 1962 to 1968, Thailand ranked fourth in number of participants but second in the total number of man years. A total of forty-two persons from Thailand received training at the Institute during the period 1962 to 1970. Possibly as many as ten of these were from Kasetsart University and most of the remainder were from the Rice Department. Subjects studied included agricultural engineering, statistics, breeding, agronomy, plant pathology, entomology and soil chemistry.

In addition to training programmes, the IRRI has provided early generation bulk hybrid seed and pedigree lines of several crosses between short-strawed parents from the IRRI and Thai recommended varieties. Although much of this material proved to be unadapted or unacceptable due to grain quality, the variety RD2 was selected from this cooperative programme. In addition, the deep water dwarf lines currently undergoing tests were selected from a bulk hybrid population provided by the IRRI. The IRRI experimental lines and varieties have also been used as parents in crosses with Thai varieties in the Thailand breeding programme.

Several cooperative experiments with herbicides, international blast tests, and trials with different types of nitrogenous and phosphatic fertilisers have been underway for one or more years.

Other assistance provided by the Institute includes determination of amylose content on all recommended varieties and selected experimental lines, maintenance of seed storage facilities for Thai genetic stocks and provision of research publications. The IRRI also provided a travel grant to permit two Thai entomologists to observe the rice gall midge research work in India.

The Rice Department has reciprocated by assisting the IRRI in screening approximately 2000 IRRI breeding lines for resistance to yellow orange leaf virus, bacterial leaf blight and blast. Recently, the IRRI experimental lines were tested in the Department for resistance to rice gall midge. Also, an International Yield Trial containing mostly IRRI selections was grown at two locations to determine their performance under Thailand conditions.

Seeds of promising lines, a few bulk hybrids and the newly released varieties RD1, RD2 and RD3 have been provided for testing and use by the IRRI research programme.

To summarise, there is no doubt that the IRRI has had an impact on the Thai rice research programme in many ways and it would be difficult to name all the persons and research work affected. However, it appears that the training received at the Institute together with the advice and encouragement of the IRRI staff have been the major contributions.

Rice Improvement Research in Indonesia

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Rice is the major cereal crop in Indonesia and the government has, since 1959, been striving to become self-sufficient in this staple food. The First Five Year Development Plan set the target that rice production should be increased from 10.53 to 15.40 million tons in the period 1969-1974. To realise this target, the government intensified the BIMAS programme in providing farmers with good seed of improved varieties, fertilisers, insecticides and recommendations on better cultural practices.

The introduction of IR5, IR8 and C4 from the IRRI brought a new phase in rice production. These varieties are high yielding and early maturing. The acceptance of the farmers, however, differed by regions. IR8 lost popularity very soon because it is susceptible to bacterial leaf blight and has very poor milling and eating qualities. IR5 is moderately resistant to bacterial leaf blight, is widely adapted to various growing conditions, but has poor eating quality and is moderately susceptible to sheath blight. C4 has excellent milling and eating qualities, matures early, but shatters easily and is moderately susceptible to both bacterial leaf blight and sheath blight.

The future research programme therefore should be directed toward development of improved varieties which are resistant to major diseases, have better eating quality, are higher yielding and have the good plant type of IR5 or IR8. The optimum yield can only be obtained by proper cultural practices: soil preparation, spacing, water management, fertiliser and insecticide applications, weeding and better methods of harvesting and processing. More studies in all of these fields are badly needed.

ORGANISATION AND OPERATION

At the present time rice research in Indonesia on production and protection is mostly conducted by the Central Research Institute for Agriculture and, to some extent, by the Faculties of Agriculture. The Institute has 25 experimental farms ranging in size from 2 to 40 hectares. They are located on various soil types and altitudes. Fifteen are in Java, four in Sumatra, three in Kalimantan and three in Sulawesi.

To maximise the efficient use of limited funds and personnel, an integrated rice research programme is urgently needed. To meet this goal, the National Rice Research Programme was established in July 1970, organised into three task forces: (1) production and protection, (2) economics, processing and marketing, and (3) extension, education and training. The specific projects underway are as follows:

Breeding

(a) Development of improved varieties that are high yielding, have good milling and eating qualities, are resistant to major pests and diseases, with moderate threshability, early maturity, moderate grain dormancy, and photoperiod insensitivity.
(b) Conducting yield trials.
(c) Collecting and screening all local rice germ plasm.

Agronomy

(a) Research on fertiliser requirements and methods of application.
(b) Spacing — fertiliser-variety trials.
(c) Weed control.
(d) Multiple cropping.

Physiology

(a) Breaking grain dormancy.
(b) Studies on physiological disorders.
(c) Water management.
(d) Phytotoxicity of herbicides.

Entomology

(a) Screening of varieties resistant to stem borer and gall midge.
(b) Screening of new insecticides.
(c) Methods of application of promising insecticides.
(d) Surveys of pest problems.

Pathology

(a) Screening of varieties resistant to blast, bacterial leaf blight, leaf streak and sheath blight.
(b) Survey of the distribution of virus diseases.

Marketing and Economics

(a) Asian Development Bank survey on rural credit in Central Java.
(b) National fertiliser study in Indonesia (financed by the World Bank).
(c) Study on the marketing aspects of rice-price policy in Java.

Processing and Storage

(a) Survey on milling output of PN Pertani Rice Mills in Java.

(b) Survey on rice marketing, processing and storage in Indonesia.

Extension

(a) Rice intensification study (financed by the World Bank).

(b) Study on the farmers' acceptance of improved technology in Java, Lampung and South Sulawesi.

Demonstration

(a) Gogo rantjah pilot projects in Java and Lombok.

(b) Demonstration pilot and extension farms on adopting new varieties and improved cultural practices.

Training

(a) Training programme on rice production, seed inspectors, seed growers, plant protection, and agricultural statistics.

(b) Agricultural development and extension methods.

New findings of basic research that have been achieved with various projects or disciplines remain to be tested over all the country by multi-location tests. The trials will be conducted by cooperation of the research institutes, faculties of agriculture, directorate of agricultural technique, and provincial extension service.

Evaluation of the trial results and formulation of the next research programme will be discussed twice a year in the Rice Workshop. If this forum decides that new techniques or promising lines have proven merits for adoption in the region, these would then be made available to the extension agency for further demonstration on farmers' field.

COOPERATION WITH THE IRRI

Cooperation with the IRRI has been intensified in various fields such as supplying breeding materials, collecting rice germ plasm, conducting special insecticide and herbicide trials, conducting international blast uniformity tests and providing short-term and advanced training.

The Institute has received more than 1500 selections from the IRRI and some of the promising lines have been extensively used as parents in hybridisation programmes.

The IRRI also helped the Institute in screening of pedigree selections for moderate amylose content. Last year, eight hundred seed samples of 10 grams each were sent to the IRRI for amylose content analysis. The results were very useful in screening pedigree selections derived from the progenies of the back cross IR5 X Syntha. Promising lines with IR5 characteristics, better eating quality, and more resistance to bacterial leaf blight have been isolated.

The Institute has participated in international uniformity tests since 1962. These tests were conducted in North and South Sumatra, West Java and South Sulawesi. Some of the varieties resistant to major races were used as parents for developing varieties resistant to blast.

One of the most important IRRI contributions is the training programme. To date 27 Indonesian scholars have been trained at IRRI in various disciplines: breeding (3), agronomy (4), entomology (2), statistics (2), agricultural economics (1) and rice production (15). The duration of the training ranged from four months to two years. Five scholars have received M.Sc. degrees and more scholars are expected to be trained at the IRRI in the future.

The East Pakistan Accelerated Rice Research Institute

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Rice Research in East Pakistan began in 1910-11 with the appointment of an Economic Botanist and performed useful services to the province, especially between 1920 and 1941. From 1941 to 1960 a general decline occurred due to a number of reasons. A most serious blow fell in 1963 when the East Pakistan Agricultural Research Institute lost its experimentall fields which were taken for establishment of a new second capital of Pakistan. It might be said that from 1963-1966 rice research was non-existent.

"REBIRTH" OF RICE RESEARCH

The steady increase of population in the already overpopulated province, and the increasing deficit of food production during the 1960's, gave cause for concern among government officials, scientists and others. With the assistance of the Ford Foundation and the International Rice Research Institute, interest in improving rice production technology was stimulated, which resulted in reactivation of rice research in 1966.

Two important events preceeded the "rebirth" of rice research: (1) the substantial grant from the Ford Foundation to IRRI for the purpose of assisting East Pakistan in rice research, and (2) the decision by the Government of East Pakistan to purchase 650 acres of land near Joydevpur, about 22 miles North of Dacca, for agricultural research.

IRRI placed a rice advisor in East Pakistan in early 1966 and much of his efforts were devoted to acquiring irrigation facilities, temporary buildings, etc. to set up the research facilities. The first experimental crop, which included 303 IRRI selections, was planted at the Savar Dairy Farm in the Aus season of 1966. The Amon crop of 1966 and the Boro crop of 1966-67 were also planted at the Savar Dairy Farm. Part of the 1967 Aus crop was planted on the newly acquired land near Joydevpur and all subsequent 'main station' crops have been planted there.

During the period 1966-68 the high yielding capacity of IR8 was recognised. This led to considerable enthusiasm among government officials and rice scientists

and more than one ton of seed was shipped from IRRI for wide scale testing. IR8 produced record yields in the Boro season but proved not to be adapted for the Aus and Amon seasons. The acreage planted to IR8 in the Boro season was 156,000 in 1967-68, 360,000 in 1968-69, over 400,000 in 1969-70, and more than 500,000 — roughly 25% of the total Boro acreage — in 1970-71. Even though some characteristics of IR8 are not desirable, it can be considered as a very successful improved variety for the Boro season in East Pakistan. More important than gaining acceptance as a standard variety, IR8 gave strong hope and encouragement that high yielding varieties for Aus and Amon seasons could be obtained through intensive research.

A decision was made in 1966 to attack the varietal improvement problem by two simultaneous approaches. The first, which might be considered as an emergency program, consisted of rapid introduction and screening of large numbers of varieties, selections, and early generation lines from outside sources for adaptability and performance under local conditions with the hope that a few superior varieties would be rapidly identified and planted on a wide scale. The second approach was to identify adapted varieties and selections with high yield potential and other desirable characteristics from introductions and cross these with the best local varieties to combine the outstanding features of both.

PARTIAL REORGANISATION — EPARRI

During 1968, a major step in rice research took place with the formation of the East Pakistan Accelerated Rice Research Institute (EPARRI) under which all rice research was to be carried out. Although EPARRI remained in the Agricultural Research Institute, under the Department of Agriculture, it was the first move toward a multidisciplinary approach in rice research. The disciplines represented in EPARRI were breeding, plant physiology, agronomy, entomology, and plant pathology. The staff members were selected from the Agricultural Research Institute. About 90 acres of land at Joydevpur was assigned to EPARRI, irrigation facilities were installed, and the first experimental crop under controlled irrigation was planted in the Boro season 1968-69.

TRAINING

As the Accelerated Rice Research Institute project began to function it was obvious that the quantity and quality of scientists necessary to conduct the level of research needed to solve the major problems in rice production were not available. Scientists from various disciplines in the Agricultural Research Institute were selected and sent abroad for training. Most of the trainees were sent to IRRI for one year of training under the IRRI senior staff members, or 2 years of training at IRRI combined with work toward the M.S. degree at the University of the Philippines College of Agriculture. As the first trained group began to return and serve as a nucleus, more emphasis was placed on training to the Ph.D. level. A total of 22 scientists have received varying degrees of training todate and a much larger programme for both the M.S. and Ph.D. levels has been approved and will be financed by USAID.

PHYSICAL FACILITIES

After the East Pakistan Rice Research project began to gain momentum, it was realised by all concerned that improved physical facilities such as laboratories, offices, library, seed drying, seed storage, greenhouses, instruments, etc: would be

needed in order to utilise efficiently the trained personnel who were beginning to return to work on problems of rice production. At the request of the Pakistan Government, Ford Foundation made a special grant in 1967, in addition to the on-going grant to IRRI, to supply the foreign exchange component needed to construct the necessary buildings and to purchase equipment. The Government of Pakistan provided funds for all local materials and labour. After several delays, the planned facilities are now almost complete.

A dormitory designed for trainees in rice production training is in the last stages of planning. Construction will begin in the dry season of 1971. Agricultural extension personnel and officers of other agricultural agencies will be continuously brought up to-date in the latest developments and findings in rice research. This dormitory-training building will enable one of the very important divisions of the institute to function more efficiently.

AUTONOMY FOR RICE RESEARCH — EPRRI

From the very modest beginning of a new phase of rice research in 1966, through the somewhat expanded EPARRI in 1968, it became increasingly obvious that insufficient flexibility in administrative matters, financing, staffing, salary adjustments, purchasing, and general operation was seriously limiting the rapid development of a good rice research capability. Planning for a semi-autonomous organisation was begun in 1968. After several proposals were submitted, and some opposition overcome, a scheme for a semi-autonomous organisation named "East Pakistan Rice Research Institute" (EPRRI) was approved by the Central Government in October, 1970 and began functioning in November, 1970.

The institute is administered by a board which has full authority to determine and execute its policies and undertakings, within the framework of policy directives issued by the government of East Pakistan and subject to the general control of the Agricultural Department. The board consists of 13 members, with the majority being officers of the provincial government. Assignments to the Board are made to the offices or positions and not to individuals.

EPRRI is made up of 10 technical divisions: (1) Breeding, (2) Agronomy, (3) Soil Chemistry, (4) Plant Pathology, (5) Entomology, (6) Plant Physiology, (7) Rice Technology, (8) Communications, (9) Statistics and Agricultural Economics and (10) Agricultural Engineering.

The main station of EPRRI consists of 165 acres of land near Joydevpur and there are four substations: (1) Comilla (71.5 acres), (2) Dinajpun (30 acres), (3) Habiganj (82 acres), and (4) Barisal (20 acres). Combined, the five locations are representative of the entire province.

RICE VARIETAL IMPROVEMENT, 1966 — 71

During the period 1966-71 more than 7,000 IRRI lines and a few varieties from other sources were introduced, tested and evaluated at 3 or 4 locations during the 3 major crop seasons. A few IRRI selections proved to be well adapted and demonstrated sufficient merit to be considered for varieties. These superior selections were then tested intensely in a coordinated effort by the various divisions of the rice research unit for yield capability, disease resistance, insect resistance, grain quality, growth duration in different seasons, cold tolerance, photoperiod sensitivity,

optimum planting dates, optimum spacing, and fertilizer response. Three new varieties; IRRISAIL, CHANDINA, and an as yet unnamed selection IR272-4-1-2, which are well adapted to 14 of the annual total of 24 million acres, have been released to farmers and are now at varying levels of commercial production. These varieties are superior to those previously grown, both local and introduced. When the new varieties were released, the basic information concerning their optimum management was made available through the extension services. Several other IRRI lines that show variety potential are now undergoing intensive evaluation.

During the same period that thousands of lines were introduced from outside sources and tested, local varieties were being studied for desirable characteristics. A number of crosses have been made between the best adapted IRRI selections and local varieties with desirable features. Progenies of 46 crosses are in the F_4 and later generations, and progenies from 87 crosses are in the F_2 and F_3 generations. An additional 75 crosses have been made since June, 1970.

A number of promising selections of the earlier crosses are presently being evaluated for varietal suitability at several locations in the province. During the past year, 1,049 selections were made from 4,175 hybrid lines and are undergoing screening for adaptation. There are strong indications that most of the future varieties will come from this hybridisation programme.

Some of the results of this new and stronger rice research programme are:

1. A coordinated multi-disciplinary effort in solving problems in rice production has been implemented.
2. Rice research is now under a semi-autonomous organisation known as the East Pakistan Rice Research Institute which allows a high degree of flexibility in its operation.
3. The selection of staff personnel and trainees is open to all candidates and not restricted to officers of the Department of Agriculture.
4. Adequate facilities for multi-disciplinary research have been provided.
5. The level of competence of research scientists is being raised through an extensive training programme.
6. New varieties of rice that are well adapted to 3 of the 4 main crop seasons, and that can be successfully grown on 14 million acres, together with detailed information for their optimum management, have been released. The area planted to the new varieties is increasing in direct proportion to the period of time since their release.

At this early stage of development of a relatively new concept of research, there are strong indications that EPRRI will exert a powerful influence in significantly raising the level of food production in East Pakistan and at the same time serve as a model for creating more effective research in crops other than rice.

The All-India Coordinated Wheat Improvement Project

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In outlining the set-up of the All-India Coordinated Wheat Improvement Project, I shall digress to review the evolution of wheat improvement work in India. As a food crop, wheat has special significance in our agriculture. Though second in importance on an All-India basis, it is the most important crop in central and north-western India. It is not surprising therefore that the crop was the first to be taken up in India for improvement by the agricultural departments. Systematic work was initiated during the first decade of this century at the Imperial Agricultural Research Institute at Pusa, in Bihar. This was extended to Lyallpur in the Punjab and later to Kanpur in Uttar Pradesh. Niphad in Peninsular India and Hoshangabad in Central India also undertook wheat varietal improvement during the fourth and fifth decades.

Wheat research was transferred to its present site, at the Indian Agricultural Research Institute, in 1935.

Earlier attempts at isolating strains excelling in yield and quality characteristics and the synthesis of desirable plant characters involved hybridisation to incorporate disease resistance from exotic varieties obtained through international cooperation, notably Australian. The early Indian wheat improvement work, carried out at about half a dozen centres, was outstanding as judged from the extensive acreage grown under selected varieties, though it was mostly 'individual breeders' enterprises. The Indian Agricultural Research Institute has contributed significantly to the number of successful varieties grown. This was essentially due to the contributions of veteran Indian wheat breeders, notably the Howards, followed by Dr. B. P. Pal. Excellent wheat improvement work has been accomplished also by Ch. Ram Dhan Singh in the Punjab and other breeders in Uttar Pradesh, Madhya Pradesh and Maharashtra.

Dr. Pal's continued association with the federal wheat improvement efforts, extending over about four decades, laid down the basis for the Coordinated Wheat Rust Control Project in the early 1950's. The expansion of this work resulted in the addition of four of the existing six breeding centres under unified control, with coordination from the IARI. Wheat improvement work progressed at these IARI stations and at 18 other stations in the states during the 1950's.

THE ALL-INDIA COORDINATED WHEAT IMPROVEMENT PROJECT

Work proceeded for about a decade at the IARI centres in a coordinated manner, but the State centres functioned independently. All centres however, reported progress of their work to the Indian Council of Agricultural Research. In 1961, the ICAR initiated country-wide coordination in wheat improvement work with Dr. A. B. Joshi, Head of the Division of Botany, IARI, as the part-time Project Coordinator. At that time not all of the states cooperated in the All-India Coordinated Wheat Improvement Project and the subsequent withdrawal of federal supporting funds in 1961–62 put some added strain on the collaborative effort.

In 1964 I was designated as part-time Wheat Project Coordinator, following the visit of Dr. N. E. Borlaug of the Rockefeller Foundation to India in November 1963. Dr. Borlaug's visit, at the invitation of the Government of India, was followed by the assignment of Dr. R. G. Anderson, Associate Wheat Geneticist from the Rockefeller Foundation, to assist with the wheat improvement research.

ORGANISATION AND PROCEDURES

The coordinated programme aims at pooling of resources and ideas of research workers of the Central and state organisations in tackling the chain of wheat production problems in the various producing areas. Previously most of the wheat breeders, working at over two dozen wheat research centres scattered over the country, were largely isolated from one another. In order to supply the central stimulus and a sense of belonging to the project, a common programme of work was devised to encourage individual workers to cooperate and to trust each other in pooling their materials for cooperative testing. To start the Coordinated Wheat Improvement Programme three series of coordinated trials were set up:

(1) Initial evaluation trials (involving newly bred varieties).
(2) Uniform regional trials (entries promoted from initial evaluation trials).
(3) National trials (widely adapted varieties picked from the uniform regional trials).

The wheat acreage of over 15 million hectares now under cultivation in India, and extending over about fifteen states, is divided into five agro-climatic zones:

(1) Northwestern plains zone
(2) Northeastern plains zone
(3) Central zone
(4) Peninsular zone
(5) Northern hills zone

Within these zones trials are conducted under various levels of fertility and of irrigation (and rainfed), and with optimum as well as late sowing dates. The organisation of the Project is shown in *Appendix I* and the main functions are listed in *Appendix II*.

The Project provides for ten properly equipped main centres and six subcentres, with a more or less uniform staffing pattern and facilities. The work has been strengthened by supporting pathology laboratories and by establishing two off-season nurseries — one in the southern and the other in the northern hills.

Since *macaroni* wheats (*Triticum durum*) are cultivated over sizeable areas of the Central and Peninsular Zones, and *emmer* wheats (*Triticum diococcum*) in the Peninsular Zone, these are also included for improvement and evaluation.

A programme of approximately 400–500 replicated field trials is finalised at the 'Annual Wheat Workers Workshop', normally held in August each year. Packaging of seeds and conduct of trials is arranged by the Zonal Coordinators with the help of the Project Coordinator. In addition, 'National Genetic Stocks Nurseries' of new selections from within and outside the country are planted each year at most of the wheat breeding centres in the country to enable the breeders to utilise the widest possible base of plant germplasm for their improvement work.

Coordinated agronomic and pathological testing programmes have also been developed and are finalised during the annual workshop meetings. So far, studies in wheat quality and bio-chemistry have been confined to evaluation of varieties at the various stages of development. Only milling and nutritional qualities such as protein content, *Pelshenke* and sedimentation values are normally studied.

BENEFITS FROM THE COORDINATED PROJECT

Both the speed and quality of wheat breeding have improved. The Project has permitted detailed and extensive evaluation of an enormous number of indigenous and foreign-bred varieties each year. All the research centres are now supplied with an abundance of up-to-date varieties and hybrid materials supplied through exchanges between the centres, from the Coordination Centre at Delhi, or from outside the country from CIMMYT and other cooperating organisations.

The coordinated programme enabled us to observe and test the fertiliser-responsive 'Mexican Dwarf' Wheats which proved to be suited to intensive culture under Indian conditions, long before our own 'Dwarf Wheats Breeding Programme', initiated in 1961 at the Delhi Centre, was in position to meet the demand of the abrupt change in governmental policy which placed new emphasis on intensive agricultural production. On the basis of a restricted number of sowings our wheat breeders were able to propose the large scale trials of the 'Mexican Dwarfs' as early as 1964.

The Indian 'Seed Procurement Team' supervised the selection of 18,000 tons of first quality Lerma Rojo seed from Mexican farmers' fields in the two States of Sonora and Baja California. The seed arrived in India in time for the 1966–67 sowings. Movement of such a massive quantity of seed-wheat was, until 1966, an all-time record of plant introduction. This enabled India to become self-sufficient with regard to seed for the 'High Yielding Wheat Varieties Programme' four years ahead of the scheduled date.

The red-grained Lerma Rojo was replaced by the amber-grained dwarfs viz., KALYANSONA, SONALIKA, SAFED LERMA and CHHOTI LERMA which were selected by Indian wheat breeders from the several hundred highly segregating or mixed Mexican germplasm lines received during 1963–64. Though selected after minimal observation and testing, these varieties have so far remained unsurpassed in yield and in resistance to rust diseases prevalent in India. They also continue to outyield the varieties released by CIMMYT since 1964.

The first country-wide 'National Wheat Demonstrations Programmes' of 1965-66 and 1966-67, planned and conducted by the wheat breeders, convincingly demonstrated the possibility of more than doubling the per acre wheat yields under

irrigation. The expansion of the country's fertiliser production programme was a strong contributing factor in the Green Revolution.

Though not considered desirable quality-wise, the existing 'dwarfs' or 'shorties' (as they are sometimes called) are holding ground due to their superior yield and rust resistance. It is expected that new superior-yielding and disease-resistant dwarf wheats with more acceptable quality will be ready for release in 1971.

The dwarf wheats are contributing to the modernisation of Indian agriculture generally since their cultivation under precision and mechanised farming, with use of machines for drilling of seeds, for applying fertilisers, and for harvesting and threshing operations demonstrates the importance of modern production methods in producing dependably higher yields.

The strengthening of the All-India Coordinated Wheat Improvement Project in 1965 and the introduction of the high yielding 'Mexican Wheat' germplasm made it possible for India to increase wheat production from about ten million tonnes in 1965–66 to over 20 million tonnes during 1969–70, *Appendix III.* India officially celebrated the 'WHEAT REVOLUTION' in 1968. Further federal support for the wheat project has been sanctioned and is expected to become effective in 1971.

LINKAGES WITH CIMMYT AND OTHER FOREIGN AGENCIES

The foregoing account of the coordinated programme identifies the linkage with the CIMMYT programme, particularly from 1963 when Dr. N. E. Borlaug first visited India for discussions on future strategy for increasing wheat production. Although the AICWI project is essentially an Indian programme, technically manned by Indian scientists, we have sincere pleasure in acknowledging grateful thanks for the advice and help given by the Rockefeller Foundation scientists, notably Drs. Borlaug and R. G. Anderson. We greatly value this association that brought wheat breeders of India, the United States and Mexico closer together. There is a continuing free exchange of materials and of research interests with CIMMYT, the F.A.O. and other international organisations. We want to further develop and strengthen this cooperation with our friends and well-wishers.

ALL-INDIA COORDINATED WHEAT IMPROVEMENT PROJECT
(Indian Council of Agricultural Research)

PROJECT COORDINATOR
All-India Wheat Improvement Programme
based at the
INDIAN AGRICULTURAL RESEARCH INSTITUTE,
NEW DELHI

Principal Investigator in WHEAT AGRONOMY

Principal Investigator in WHEAT PATHOLOGY

Principal Investigator in WHEAT BIOCHEMISTRY

Principal Investigator in WHEAT PHYSIOLOGY

COORDINATION IN THE 5 AGRO-CLIMATIC WHEAT ZONES OF INDIA

1. N. W. Plain Zone
Zonal Coordinator

STATES & CENTRES

Punjab	(M.C)
Haryana	(St.C)
Delhi	(M.C)
Rajasthan	(M.C)
W. Uttar Prad	(M.C)

2. N.Eastern Pl. Zone
Zonal Coordinator

STATES & CENTRES

E. Uttar Pradesh	(M C.)
Bihar	(MC & SC)
W. Bengal	(S.C)
Assam	(T.C.)
Orissa	(T.C.)

3. Central Zone
Zonal Coordinator

STATES & CENTRES

Madhya Pradesh	(M.C)
Gujarat	(S.C)
S. East. Rajasthan	(T.C.)

4. Peninsular Zone
Zonal Coordinator

STATES & CENTRES

Andhra Pradesh	(S C)
Maharashtra	(M.C)
Mysore	(S.C)
Madras	(S.C)

5. Northern Hills Zone
Zonal Coordinator

STATES & CENTRES

Jammu & Kashmir	(St C)
Uttar Pradesh	(M.C)
Himachal Pradesh	(St. C & S.C)
Bihar	(S.C)
West Bengal	(S.C)

Note: M.C = Main Centre; S.C = Sub-centre; St.C = State Centre; T.C. = Testing Centre

APPENDIX II

MAIN ACTIVITIES OF WHEAT COORDINATION

Pooling of resources and ideas of the Central and State Organisations for the multi-facet attack on wheat improvement problems cutting across various disciplines and geographic areas through:

(1) Intensification of wheat breeding efforts at main centres (10), sub-centres (6), and off-season nurseries (2), with supporting pathological disciplines, by growing new genetic stocks in national and international nurseries, and arranging for exchange of hybrid material between workers.

(2) Coordinated testing of newly bred wheat varieties at all stages of development under the different conditions of wheat production in India.

(3) On-the-spot evaluation of the performance of promising varieties through zonal meetings of wheat research workers.

(4) The holding of annual workshops of wheat workers.

(5) Appraisal of the results of the previous year's field and laboratory tests at the All-India workshop meetings organised for each of the main spheres of activity.

(6) Focussing of attention of research workers on new problems and helping in over-coming bottlenecks to progress of research.

(7) Giving publicity for the adoption of new research findings.

(8) Advisory and training.

APPENDIX III

TOTAL AREA, PRODUCTION AND AVERAGE YIELD OF WHEAT IN INDIA 1960–61 to 1970–71

Year	Area (000 ha)	Production (000 tons)	Average Yield (Kgs/ha)
1960–61	12,927	10,997	851
1961–62	13,570	12,072	890
1962–63	13,950	10,776	793
1963–64	13,490	9,853	730
1964–65	13,460	12,290	913
1965–66	12,656	10,424	824
1966–67	12,838	11,393	887
1967–68	14,917	16,568	1111
1968–69	15,958	18,651	1169
1969–70	15,834	20,400	1263
1970–71	16,800	21,250	1265

The All–India Coordinated Maize Improvement Project

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Maize is one of the most important food crops in India as it ranks next to rice, wheat and sorghum in production. Both area and production under maize have increased, from 3.26 million hectares with 2.05 million tons in 1949–50, to 5.86 million hectares with 5.67 million tons in 1969–70. During the past two decades, the area and production have increased at 3.8 and 8.4% respectively. This suggests the potentialities for the future. It is worthwhile to note that over 90% of the maize is used as a human food. Of course, tremendous potentialities for industrial uses and for animal feed also exist. The poultry industry alone is likely to consume 1.50 million tons of maize if the per capita consumption of eggs, as visualised in the current Plan, is raised from 8 to 40. The maize production target for the current Five Year Plan has been fixed at eight million tons.

The All-India Coordinated Maize Improvement Scheme is devoted to the development of high yielding hybrids and composite varieties. It is also engaged in the identification of cultural practices and disease and pest control measures that will lower production costs and maximise profits.

Maize improvement work in India has been underway since 1940 but before 1957 little improvement was achieved. By the early 1950's most maize workers realised that the Indian germplasm had limited genetic variability. Most of the Indian varieties belonged to the two groups 'Cuban Yellow Flint' and 'Early Yellow Flints' (Wellhausen and Grant, 1954). For successful implementation of the maize improvement programme a comprehensive collection of exotic germplasm was needed.

The Coordinated Maize Improvement Scheme, the first coordinated, nation-wide crop improvement project, was launched by the Indian Council of Agricultural Research in 1957, with active cooperation of the Rockefeller Foundation. Extensive collections of maize germplasm were made from the U.S.A. and Central and South America, particularly from the Mexican and Colombian maize programmes of the Rockefeller Foundation. Through rapid screening of these introduced maize materials, and also those previously available in the country, in multi-location trials, in less than four years four hybrids were 'released' for commercial cultivation.

ORGANISATION

The Coordinated Maize Improvement Scheme has sixteen research stations representing the four major maize growing regions or zones in the country; the

Himalayan region, the North-eastern zone, the Northern-western zone, and Peninsular India. Each zone has a main station and a number of sub-stations *(Appendix)*. Most of the stations are adequately staffed to handle the breeding, agronomic, pathological and entomological investigations.

In India, agriculture is a state subject. The breeding, and part of the agronomic component, are completely financed by the Indian Council of Agricultural Research while the disciplines of entomology, pathology and part of agronomy are supported by PL 480 funds. Administrative control of the various research stations rests with the respective state departments of agriculture or agricultural universities. The research programmes are planned jointly by all research workers at the annual workshop meetings. There is a free exchange of information, data and seed materials among the various research stations.

PROGRESS

Breeding

Following the establishment of the Coordinated Maize Improvement Scheme in 1957, extensive germplasm collections were made from the U.S.A., Columbia and Mexico. A number of significant findings related to the development of maize hybrids in India which emerged were:

1. Indian maize germplasm had limited genetic variability and the incorporation of suitable exotic germplasm was essential for the successful development of high yielding hybrids.
2. The elite inbred lines of established maize hybrids from the corn belt of the U.S.A. could not be used directly in India because of limited vigour and disease problems.
3. The use of short-term inbred lines was more desirable, due to the lack of vigour of higbly inbred materials.
4. Multi-location testing expedited the identification of high yielding, widely adapted genotypes in a relatively shorter period of time.
5. Alternate types of maize hybrids such as the double top-crosses have proved to be more acceptable because of convenience in production and wider adaptability. In fact, three hybrids under production are double top-crosses.
6. Genetic investigations with a number of heterozygous populations of maize have shown that the additive genetic variance was considerably more important than the non-additive genetic variance. It has thus been possible, through the judicious use of varietal crosses, to develop composite populations which have given yields comparable to the hybrids under production.

Following the release of four hybrids (Ganga 1, Ganga 101, Ranjit and Deccan) in 1961, five more hybrids have subsequently been developed and released for commercial cultivation in the various maize growing regions of the country. Himalayan 123 is a yellow double-cross recommended for the higher elevations. Ganga Safed 2, a white double top-cross has given very high yields through the northern plains. Hi-Starch, a white dent double top-cross is suited for the starch industry. Ganga 5, the latest hybrid released, in 1968, besides giving high yields and wider adaptability is highly resistant to brown stripe downy mildew *(Sclerophthora* raysseuevar. *zeae* Payak and Renfro). Maize hybrids have given about 30–35% or more yield than

local varieties under recommended cultural practices. These hybrids are resistant or tolerant to the major leaf diseases and pests.

As a next step toward increasing yield performance, complex populations involving a large number of selected elite varieties and synthetics, called 'Composites', were developed from which still higher yielding hybrids can be developed. Some of the composites in advanced generation have given yields which are comparable to the best hybrids under production. In 1967, the six composites Vijay, Kisan, Sona, Vijay, Amber and Vikram were released for commercial cultivation. The seeds of these composites can be more conveniently multipled than those of the hybrids. These composite populations have been reselected through reciprocal recurrent selection, recurrent selection, half-sib family selection, unit selection and mass selection. The reconstituted versions of these composites are not only better in yield but have greater resistance to the foliar diseases. Inbred lines, selected from these composite populations, are being evaluated in double crosses.

With the release of maize hybrids, and of new sorghum and millet hybrids, a seed industry was organised for the first time in India. The National Seeds Corporation was set up in 1963 as a Government of India undertaking and many seed growers associated themselves in the production of hybrid seed. Currently, over one million acres are planted to maize hybrids and composites.

Pathology

Maize is attacked by a number of diseases but the important ones are: leaf blights *(Helminthosporium turcicum, H.maydis)*, brown stripe downy mildew *(Sclerophthora raysseae* var. *zeae)*, brown spot *(Physoderma maydis)*, rust *(Puccinia sorghi)*; Cephalosporium stalk and ear rot *(Cephalosporium acremonium)*, bacterial stalk rot *(Erwinia carotovora* var. *zeae)*, pythium and stalk rots. The pathologists are working with the breeders in the screening of inbred lines, hybrids and composites for the various important diseases. Sources of resistance to most foliar diseases have either been identified or acquired. Maize hybrids and composites show a fair degree of resistance to the foliar diseases.

Techniques for artificial inoculation against most of the stalk rots have been developed and resistant genotypes are being identified. The male parent of Ganga Safed 2 (CM 600) has a high degree of resistance to bacterial stalk rot and cephalosporium. Other lines with resistance are CM 104 and CM 103. Anitgua Gr. I (CM 500) has shown considerable resistance to brown stripe downy mildew. One to two cycles of recurrent selection has been carried out in Sona, Vijay, Kisan and Jawahar for a number of foliar diseases and stalk rots.

Entomology

A number of pests cause considerable damage but the stem borers *(Chilo zonellus* and *Sesamia inferens)* are the most important, seriously limiting production of maize in north India. Synthetic diets have been perfected for the borers and it is now possible to rear them on a mass scale. Maize germplasm has been evaluated under manual infestations for relative resistance. Antigua Gr. I, Caribbean Flint composite and Barbados Gr. I have shown considerable resistance.

A programme for incorporating combined resistance for stem borer and stalk rots has been initiated in two composites, CM 500 and Caribbean Flint composite, which have a reasonable degree of resistance to the foliar diseases. These resistant versions of the composites will not only serve as source stocks but will be readily used

to replace the susceptible parents. A similar improvement programme of combining disease and pest resistance will be extended to the other populations also.

Agronomy

At the various centres of the project, studies relating to the determination of ideal time of planting, economical levels of NPK application and plant population, etc. have been carried out. Plantings made ten to fifteen days before the usual date of planting resulted in higher yield at almost all locations. About 150 kg. of nitrogen and a plant population of 50 to 75 thousand plants per hectare gave the maximum yield at most of the stations. The requirement of P_2O_5 was about 60 kg per ha. while the response to K_2O was variable at various locations. Varietal differences with regard to optimum level of plant population and nitrogen level were observed. Significant response to zinc up to a level of 24 kg per ha. for some locations was observed.

PROTEIN QUALITY

Studies with a view to improving the protein quality of maize hybrids and composites through the use of opaque-2 and floury-2 genes have been underway since 1966. Recovered populations of some of the elite composites and parental inbred lines of some of the promising hybrids in the third to fourth back-cross generation are being evaluated for yield maturity and protein quality. On the basis of 1970 data, based on 6 locations, it was observed that certain opaque-2 and floury-2 populations were within 90–95% of the yield level of the best normal hybrid.

Chemical analysis of some of the recovered opaque-2 and floury-2 populations have shown the lysine (as % protein) to range from 3.97 to 4.22%, with a protein content of 9.73 to 11.8%. In contrast, Ganga 3, one of the normal commercial hybrids, had 1.64% lysine with 10.27% protein. The leusine/isoleusine ratio was also more favourable for opaque-2 maize. Biological values determined from the rat feeding trials showed that the protein efficiency ratios for opaque-2, casein and Ganga 3 were 3.38, 2.03 and 1.20, respectively.

In a poultry feeding trial conducted at the Indian Veterinary Research Institute, Izatnagar, twenty-day-old birds were fed on a ration differing only in normal maize and opaque-2 maize. The feed efficiency ratio of birds fed on normal and opaque-2 was 2.86 as against 3.00.

A feeding study, carried out in J.J.Colony of Nangloi with young children of 6–36 months of age selected from the low income group, has just been completed. In this study, 79 children were fed on opaque-2 maize as supplementary food and 77 were given skim milk as a supplementary food. It was observed that the children of the opaque-2 group gained more weight than the milk group.

PROBLEMS AND FUTURE LINES OF WORK

In spite of the development of a number of high yielding maize hybrids and composite varieties, and the identification of improved cultural practices, all has not yet been done. In recent years the overall food supply has improved due to increased wheat and rice production. The cost of fertilisers has increased markedly but the price of maize has gone down. This has led to a marked decrease in the net profits to maize farmers.

There is an urgent need for developing maize hybrids and composites which mature in 75–80 days and can give high stable yield under rainfed conditions. Identification of maize hybrids which are more fertiliser-responsive than the present hybrids also is urgently needed.

The hybrids now under cultivation have a reasonable degree of resistance to foliar disease but they are susceptible to stalk rots. Work is in progress to combine resistance to stalk rots and stalk borers. Development of resistance to 'Sugarcane downy mildew' also needs to be intensified.

Because of soft and light grains, opaque-2 and floury-2 populations have lower test weights and are also more susceptible to pests during storage. Identification of opaque-2 with normal flinty grain types would be more desired. In addition to the highly balanced amino acid composition, it is also desirable to increase the total protein content and oil percentage without adversely affecting yield levels.

REFERENCE

1. Grant, U. J. and E. J. Wellhausen. A study of corn breeding and production in India. Report to the Ministry of Food and Agriculture (1954).

RESEARCH STATIONS OF THE COORDINATED MAIZE IMPROVEMENT PROJECT

AICMIP Zone	Region	Main Station	Research* Programme	Sub-Station	Research* Programme
I	Himalayan	Srinagar	B	Almora	BA
				Bajaura	BAP
				Solan	BAP
				Kalimpong	BA
				Gangtok	B
II	Northeastern	Delhi	BAPEQ	Udaipur	BAPE
				Ludhiana	BAE
III	Northwestern	Uttar Pradesh Agr. University	BAPE	Dholi	BAPE
IV	Peninsular	Hyderabad	BAPE	Dharwar	BA
				Chhindwara	BA
				Godhra	BA
				Manjri	BE

* B — Breeding
A — Agronomy
P — Pathology
E — Entomology
Q — Quality laboratory

Part III

International Research Resources

The International Agricultural Research Centres

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I will direct my remarks to some of the complementarities between national programmes for agricultural research and development, on the one hand, and the four international agricultural research centres initially sponsored by the Rookefeller and Ford foundations, on the other.

The International Rice Research Institute (IRRI), in the Philippines, was the first of the centres to be organised and has set the pattern in terms of organisation and performance for the other three centres created until now. In his paper for this seminar Robert Chandler has described the missions of the IRRI and, by extension, the missions of the other centres. The second centre, the International Centre for Improvement of Maize and Wheat (CIMMYT), in Mexico, is an outgrowth of the collaboration begun by the Mexican Government and the Rockefeller Foundation a quarter of a century ago. Later this year CIMMYT will catch up with IRRI in a physical sense when CIMMYT occupies its new headquarters near Chapingo.

These first two centres are in the stage of adolescence and are approaching adulthood. However, the other two Centres — the International Centre for Tropical Agriculture (CIAT), in Colombia, and the International Institute for Tropical Agriculture (IITA), in Nigeria — still are in early childhood. CIAT and IITA are intended to divide the labour for tropical food crops and animal production, but it will be several years before they become fully operational.

The international centres are, relatively speaking, latecomers to the scene of agricultural research and development. And in a real sense they are junior partners to national agricultural development programmes. The contributions of IRRI and CIMMYT are sizeable and important. But the great bulk of resources — human, material, and financial — which are invested in agricultural modernisation are directed toward national programmes. These resources must come mainly from the developing nations themselves rather than from the so-called developed nations. I make this point not because it is unfamiliar to any of the members of this seminar but because it sometimes may not be kept fully in mind when, for example, the Bellagio group of lending and granting agencies sit down to discuss agricultural development.

I suggest that it is useful for us to measure the present international agricultural centres and others that may be organised in the future in terms of the requirements of national programmes and national objectives for agricultural modernisation, as well as in more global terms. I think it is useful, too, for the consumers of the research and training products of the international centres to have the predominant voice in deciding what the centres are to do. This would be a constructive form of "consumerism" and would strengthen the contributions of the international centres to national agricultural programmes.

I would offer these specific suggestions for consideration during this seminar or in other forums:

First, I would suggest that the international agricultural centres should be governed and staffed mainly by scientists from the nations of Asia, Africa, and Latin America. This is not the case now. No doubt there were practical reasons for starting the centres under other auspices, but I doubt whether these reasons continue to be persuasive. Rather, I think the international centres can be stronger in the future if the agriculturally developing nations themselves take a stronger hand in directing and operating the centres.

Second, I suggest that the "consumer" nations should set the priorities for research, training, and extension activities of the international centres. This point follows from the preceding one, but it perhaps is more difficult to achieve. The record of internationally managed organisations is not altogether encouraging. But I believe ways can be found to combine strong leadership and management with broader participation.

While I have just proposed that others should determine the priorities and operations of the international agricultural centres, I would offer these opinions about some activities that might deserve high priority:

— I believe the centres should concentrate on activities which capitalise on experience from many nations and which facilitate the flow of experience among nations. This perhaps is not a point of major difference from the way in which the centres operate now, but I raise it here to suggest that the centres, with their limited resources, should clearly emphasise their international roles and should not become preoccupied with individual national programmes which may not have much benefit for other nations. I believe that CIAT in Colombia confronts this problem now.

— The international centres should be used more fully as centres for advanced research and training for scientists who work in the agriculturally developing nations. The international institute of physics in Trieste may offer a model relevant for the international agricultural centres. The institute in Trieste offers what amounts to joint appointments to scientists who spend the major share of their time in their home countries but who come to Trieste at intervals to work with their colleagues from around the world. Among other things, this device has helped strengthen national efforts and has dampened problems of brain drain.

— Finally, I suggest that the international agricultural centres should establish stronger ties with universities and other research institutions, both in the developing nations and in the more advantaged nations. Although this is easier said than done, the centres might provide a platform for helping connect universities with action programmes in ways more productive than typically is the case now. It seems to me that North American universities in many current instances

are not productively engaged with national programmes abroad and at best have insubstantial connections with the international agricultural centres. Better ways should be found to make use of these institutional resources.

The International Rice Research Institute

ROBERT F. CHANDLER, JR
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The International Rice Research Institute conducts a comprehensive research programme on the rice plant and its management, maintains a library and documentation centre to collect and provide access to the world's technical literature on rice, operates an information service, conducts regional rice research projects in cooperation with scientists in other countries, offers a resident training programme where scientists and extension workers from rice-growing countries of the world may carry out studies of the rice plant and learn techniques of rice production, and conducts international seminars and workshops to allow participants to pool their experience and to identify important unsolved problems.

My assignment is to present the high points of our research programme and to identify future priorities. In confining myself to this topic I shall omit some important activities of both a research and non-research nature.

VARIETAL IMPROVEMENT

The development of the short, stiff-strawed, fertiliser-responsive rice varieties for the tropics and sub-tropics has been told many times and need not be repeated in detail here.

The rapid progress in improving the tall, leafy, lodging-susceptible tropical varieties was brought about by crossing them with Taiwanese varieties that carried a single recessive gene for shortness. When tall varieties were crossed with the short Chinese ones, in the F_2 generation three-fourths of the population was tall and one-fourth was short. The tall ones were discarded and the the short ones were saved for further selection. It is now clear that progress would have been slower had it not been for the presence of the simply inherited dwarfness of the Taiwanese varieties.

The IRRI named IR8 in 1966, IR5 in 1967, and IR20 and IR22 in 1969. All but IR5 carried the Dee-geo-woo-gen dwarfing gene. A summary of the characteristics of these varieties is shown in *Table 1.*

IR8 and IR5, although high yielding and widely adapted to tropical conditions, are defective in grain quality (appearance and milling quality) and are susceptible to the bacterial blight disease.

TABLE 1. CHARACTERISTICS OF THE FOUR NAMED IRRI RICE VARIETIES

Character	IR8	IR5	IR20	IR22
Flag leaf	erect	horizontal	erect	erect
Height	90–105 cm	130–140 cm	100–115 cm	95–105 cm
Lodging	Highly resistant	moderately susceptible	moderately susceptible	resistant
Growth duration (at 14°N latitude, Los Banos) Dry season (Dec. seeding)	125 days	135 days	120 days	155 days
Wet season (June seeding)	130 days	145 days	135 days	130 days
Reaction to photo-period	insensitive	weakly sensitive	weakly sensitive	weakly sensitive
Disease resistance Blast*	moderately resistant	moderately susceptible	resistant	susceptible
Bacterial leaf blight	moderately susceptible	moderately resistant	resistant	moderately resistant
Bacterial leaf streak	susceptible	moderately susceptible	resistant	moderately resistant
Insect resistance Brown planthoppers	susceptible	susceptible	susceptible	susceptible
Green leafhoppers	resistant	resistant	resistant	susceptible
Grain: Length	medium	medium	medium	long
Width	bold	bold	slender	slender
Appearance	some white belly	some white belly	translucent	translucent
Head rice recovery	low	moderately high	high	high
Amylose content	high	high	high	high
Eating quality	acceptable	acceptable	very good	very good
Dormancy	moderate	moderate	strong	moderate

* Data on blast resistance are from tests in the Philippines only.

IR22 was designed to overcome these deficiencies and it has excellent grain quality and considerable resistance to the bacterial blight. It is unfortunately susceptible to the green leafhopper *(Nephotettix impicticeps)*, which is the vector of the tungro virus disease, and it does not have the high resistance to the rice blast disease of its Tadukan parent.

IR20 has good grain quality and considerable resistance to stem-borers, to green leafhoppers and to tungro virus disease. Its plant type is acceptable and, largely because of its disease and insect resistance, it is rapidly gaining in popularity among farmers, particularly in the Philippines, East Pakistan, South Vietnam and Indonesia.

It is apparent from our varietal improvement research and testing programme that, in addition to desirable plant type and acceptable grain quality, the most important characteristics to be added are disease and insect resistance.

The Institute has embarked on an intensive crossing programme to create a series of varieties of different genetic origin that possess resistance to rice stem-borers, to brown planthoppers, and to the bacterial blight and rice blast disease. This job will require at least another 10 years.

In addition to the highly important disease-resistant qualities, new varieties must be developed that have varying growth durations from 100 days or less to as much as 150 days; yet are not photoperiod sensitive. Conversely, a few photosensitive varieties will be needed for growing in certain tropical countries in the monsoon season.

A group of cold-resistant varieties is needed for the higher elevations of the tropics and for wintertime planting in the northern parts of the tropics such as East Pakistan and northern Burma.

Research to develop varieties that are adapted to deep water but which will not grow too tall when the water remains shallow has just commenced.

Breeding for drought resistance in upland rice or for rain-fed paddy conditions is another difficult assignment that is worthy of a sizeable effort.

As all plant breeders recognise, the magnitude of the task ahead is amplified because whenever a new character is introduced into an improved variety, there is danger of losing some of the desirable characters already present in the improved parent. However, as a breeding programme goes forward it is possible to use as parents varieties or genetic lines that have several of the important good qualities in common. This obviously greatly reduces the chances of losing them.

VARIETY-FERTILISER INTERACTION

The short, stiff-strawed varieties are higher yielding primarily because they do not lodge on fertile soils or when large doses of fertilisers are applied. An example of this is shown in *Figure 1*, which presents the nitrogen responsiveness of two contrasting plant types in the sunny dry season and in the cloudy monsoon season in the Philippines.

These data were obtained on the experimental farm of the IRRI, but similar results have been obtained on experimental fields and on private farms throughout the tropical rice-growing regions of the world.

Although IR8 is now being supplanted by better varieties, the plant type remains the same, and the fertiliser responsiveness of all the improved varieties is high. It is significant to note *(Figure 1)* that in the absence of fertiliser the yield of the improved variety was the same as the traditional variety in the dry season, and was considerably larger in the wet season. Thus, the rice farmer has nothing to lose by changing to the new varieties, and he may gain a great deal depending upon the level of crop management that he is able to practice.

As is evident in *Figure 1*, there is now ample proof that when other factors are under control grain yields are highly influenced by the amount of solar energy during the last 45 days or so that the crop is in the field. This is borne out in practice,

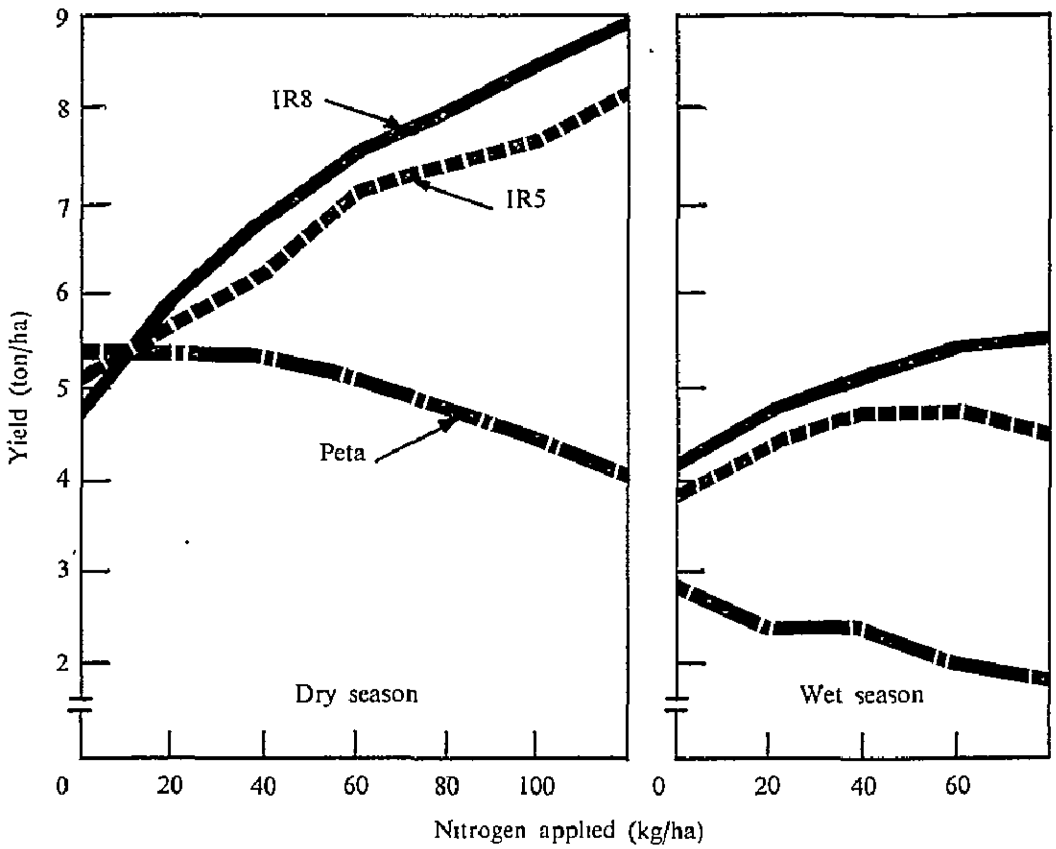

Figure 1. The nitrogen responsiveness of two contrasting plant types in the sunny dry season and in the cloudy monsoon season in the Philippines. IR5 and IR8 represent the new, short-strawed fertiliser-responsive varieties, while Peta is a typical tall tropical variety.

for the highest recorded yields of rice have been in localities and seasons receiving high amounts of sunshine, i.e., West Pakistan, the drier parts of India, Egypt and Spain.

CHEMICAL WEED CONTROL

Marked progress has been made in chemical weed control in rice during the past several years. The Institute has tested many herbicides and has identified materials and worked out methods that give satisfactory weed control in transplanted as well as direct-seeded rice. Some data obtained in the wet season of 1970 are reproduced in *Table 2*.

The complete results of these herbicide experiments will be published in IRRI's annual report for 1970. The only point to be made here is that chemicals are now available to farmers that give excellent control of grassy weeds, broadleaved weeds and sedges that can be applied in granular form only once, a few days (three to eight, depending upon the material and the method of planting) after transplanting or seeding.

The economics of some of the newer chemicals has not been worked out but 2,4-D can be applied at a cost of less than half that of hand-weeding.

TABLE 2. GRAIN YIELDS OF TRANSPLANTED AND BROADCAST-SEEDED IR22 RICE GROWN UNDER FLOODED CONDITIONS DURING THE 1970 WET SEASON IN THE PHILIPPINES, WITH DIFFERENTIAL HERBICIDAL TREATMENTS.

Herbicide	Transplanted lowland rice		Direct-seeded lowland rice	
	Rate (kg/ha) of active ingredient	Grain yield, ton/ha	Rate (kg/ha) of active ingredient	Grain yield, ton/ha
CP 53619	1.0	6.1	1.0	6.1
Benthiocarb	1.0	6.1	2 0	5.5
NTN 5006/2,4-D	2.0/0.45	6.3	2.0/0.45	6.0
2,4-D	0.8	5.9		
Untieated Control		3.9		1.2

The chemical control of weeds in direct-seeded upland (non-flooded) rice is more difficult, but, for the first time in the history of the Institute, our scientists have worked out a combination of chemicals and methods of application that may prove to be practical for farm use. The most promising materials are two of those already reported in *Table 2* for lowland rice, viz. NTN 5006 and CP 53619. The former is a new chemical made available for experimental purposes by a Japanese company, and CP 53619 is a Monsanto Chemical Co. product marketed in the U.S.A. under the trade name of 'Machete'.

INSECT AND DISEASE CONTROL

Work on the chemical control of insects has been vigorously pursued at the Institute since the beginning nine years ago. *Figure 2* shows that the use of chemicals has increased, on the average, rice grain yields by about two metric tons per hectare when other crop-growing conditions were at an optimum.

Originally the Institute entomologists showed that lindane was quite satisfactory for the control of stem borers when used as a systemic insecticide applied in granular form into the layer of water in flooded rice fields. Later, using similar methods of application and form of material, diazinon was found to be highly effective not only for stem borers but for green leafhoppers and brown planthoppers. After four years of use on the same experimental fields, the insecticide became ineffective in the control of the brown planthopper *(Nilaparvata lugens)*, apparently for the dual reason that the insects developed resistance and that there was a concurrent buildup in the soil of the population of micro-organism that readily degraded diazinon and rendered it ineffective a few days after its application.

The most promising systemic insecticide for the control of rice insects today is carbofuran. This is marketed under the trade name of Furadan.

The most exciting future developments in insect control for rice lie in the development of rice varieties with high levels of resistance to insect attack. Rice entomologists and plant breeders have proved conclusively that some rice varieties are essentially immune to attacks by green leafhoppers, brown planthoppers and the gall midge. Substantial progress has been made in creating stemborer-resistant varieties.

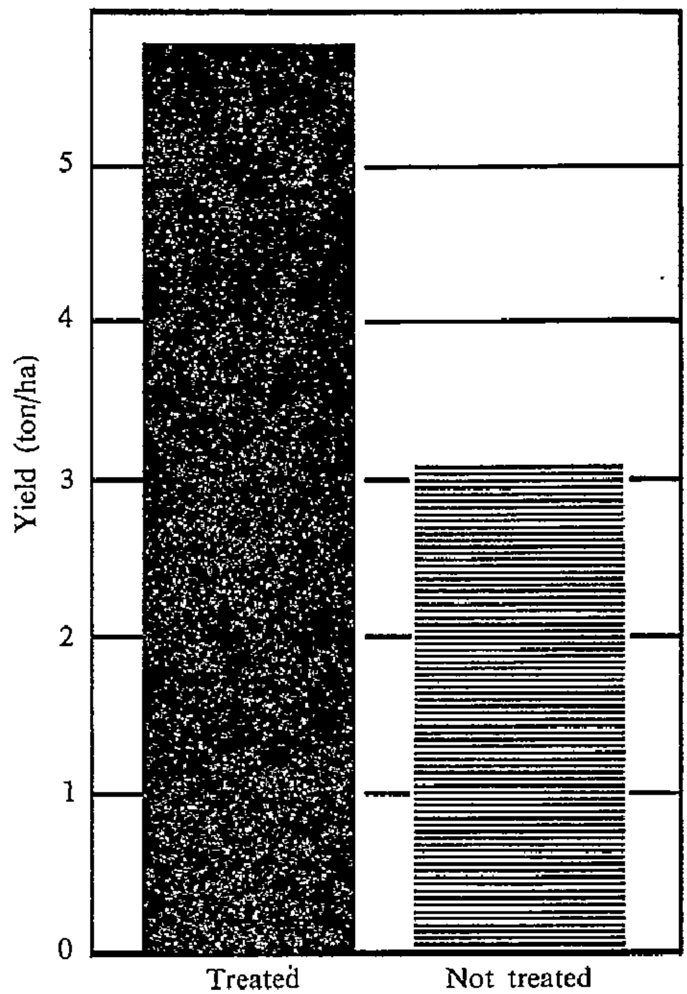

Figure 2. Average grain yield of rice for 52 replicated insecticide trials over 10 crop seasons. The treated plots received applications of either lindane or diazinon in granular form, applied directly to the paddy water.

Although the Institute's pathologists investigate the effectiveness of promising new fungicides, the major emphasis in rice disease control is placed on the development of varieties that are resistant to the major diseases. By screening the world collection of over 10,000 varieties, it has been possible to find sources of resistance to the major diseases of rice.

Breeding programmes conducted jointly by the plant pathology and varietal improvement departments have produced lines with resistance to bacterial leaf blight, to rice blast disease, and to the tungro and grassy stunt virus diseases.

Virus resistance involves entomologists as well as pathologists and plant breeders because a highly important ingredient of resistance to the virus is resistance to the vector itself. For example, the brown planthopper carries the grassy stunt virus and the green leafhopper carries the tungro virus disease.

AGRICULTURAL ECONOMICS

The Institute has conducted economic studies since its inception. Some of the earlier work was concerned with an analysis of the rice situation in tropical Asia. Then, as new varieties and methods were developed, they were subjected to economic analysis to determine their profitability as compared with the traditional practices. As these studies progress from year to year, they provide some information on the economic and social impacts of the Green Revolution.

In the Philippines, it has been possible to include farms that were being studied by other groups in 1965 and 1966 (before the new rice varieties were available) and to follow the changes after those high yielding varieties had been introduced. Some of the farms were double-cropped to rice (hence fully irrigated), others grew only one crop of irrigated rice, and some grew only rainfed paddy.

From a study in Central Luzon involving 92 farms, the total labour utilisation did not change appreciably with the introduction of new varieties. As more tractors came into use, the requirement for land preparation decreased somewhat; but this was more than offset by the increased labour used in weed control, harvesting and threshing.

A study in Laguna province of 155 farms which were growing only traditional varieties in 1966 revealed that by 1970 they had almost fully changed to the high yielding varieties. The only exception was that about one-quarter of the farmers continued to grow Intan and some glutinous varieties during the dry season when yields were higher. This was because the market price for the grain of these varieties was higher than that of IR8 and IR5. Now that IR20 and IR22 are available, it is expected that less Intan will be grown in the future; soon, higher-yielding glutinous varieties will be available to replace the traditional ones.

The Laguna study shows that during the three-year period, 1966 to 1969, production costs increased by about 90%. This increase represented added use of fertilisers and insecticides, increased use of tractors for land preparation, additional labour for harvesting, and the rise in farm wage rates.

In spite of these added costs however, net returns in 1969 were 53% higher than they were in 1966. (Net return is the difference between gross return and variable costs). When individual farmers were asked why they adopted the new varieties and continued to grow them year after year, their replies consistently indicated that it was because of the increased financial gain.

A study of a rather well-irrigated barrio in Tarlac province (in the Philippines) was carried out by Professor R. R. Huke of Dartmouth College, when he was a visiting scientist at the Institute. From 1965 to 1969 the number of farmers using Institute varieties (mostly IR8 and IR5) increased from 0 to 78%, the use of insecticides doubled, the amount of nitrogen fertiliser applied tripled, and average yields went from 1.7 to 3.0 metric tons per hectare.

Huke reports that during 1969 and the first half of 1970 30% of the houses in the barrio were rebuilt using sawn lumber and cement blocks in place of rough lumber and bamboo. The average cost per house of the new construction was P11,000. Huke attributed these improvements directly to the increased profit derived from the higher rice yields.

Much more data are needed to show the economic and social effects of the introduction of high yielding rice varieties. In the Philippines, where 44% of the

rice land is devoted to the new varieties, there is no resultant evidence that 'the rich are getting richer and the poor are getting poorer' nor has there been any detectable change in the rate of movement of people from rural to urban areas.

OTHER STUDIES

The work described above represents a small portion of the Institute's total research programme, but the topics were selected mainly because of their impact on yield or because of their general interest. The results described could have been neither so quickly obtained nor so well understood without the knowledge provided by the entire Institute staff. The Institute's approach essentially has been one of team work. The following lists a few of the other achievements of our scientists.

The plant physiologists and soil chemists have identified new areas of zinc deficiency in Asian rice soils and have developed practical ways to correct it.

The soil microbiologists have shown that nitrogen fixation by micro-organisms in flooded paddy soil is much higher in planted than in unplanted soils and that the activity of nitrogen-fixing organisms is concentrated mostly in the rhizosphere. The microbiologists have also shown that several of the organochlorine insecticides such as DDT, BHC and heptachlor are degraded rather rapidly in flooded paddy soils, although the same materials are persistent in well-drained soils.

The chemistry department, in cooperation with the plant-breeders, is making progress toward the development of rice varieties with 2% more actual protein than in average varieties.

The plant physiologists have shown that rice varieties vary considerably in their photosynthetic rates and studies are now under way to analyse the impact of this factor on yield potential.

The agricultural engineers have developed six-row and eight-row seeders whch are now being manufactured in the Philippines. These implements are designed for direct sowing on the mud surface of the puddled paddy soil and permit one man to plant one hectare in five hours (about twenty times faster than transplanting). The same department has developed new types of threshing machines and seed cleaners that are most useful to small farmers. The engineers are now designing and testing a rapid rice drier, a field harvester and a high volume thresher.

RECAPITULATION ON FUTURE RICE RESEARCH PRIORITIES

Although on-going projects and significant areas for future emphasis have been mentioned throughout this paper, for purposes of convenience and emphasis, they are summarised in this section.

No line of rice research shows more promise of future reward, in terms of increasing grain yields on tropical rice farms, than developing varieties that have high levels of resistance to the major insect pests and diseases. The results of the past few years show that the degree of acceptance of varieties by the rice farmer is closely correlated with their yielding ability under low levels of management. In the next five years we shall see much progress in this respect, and within ten years a series of varieties should be available with different growth durations and with varying eating and cooking qualities to suit the preferences of consumers around the world. The varieties will uniformly possess the short, stiff-strawed, heavy-tillering plant type, clear translucent slender grains and increased protein content of grain. They will

all have resistance to green leafhoppers, brown planthoppers, stem borers and the gall midge and resistance to most races of the rice blast disease, to bacterial blight disease, to bacterial streak disease and to other important diseases such as sheath blight, cerospora leaf spot and helminthosporium.

Another breeding procedure which deserves future emphasis is the incorporation into the germ plasm of the high-yielding varieties, the so-called 'floating gene'. It has been demonstrated at the IRRI that the introduction of the floating rice character, together with the Dee-geo-woo-gen dwarfing gene, can produce a rice variety that will remain short when the water depth is shallow, but will be able to survive severe flooding because of its capacity for stem elongation when the water depth rises. This is a way of providing flood insurance to many Asian rice farmers who live in areas where water depths of 30 to 60 cm may be encountered over extended periods in certain seasons.

It is estimated that about 20% of the rice land in South and Southeast Asia is occupied by upland rice, yet only 10% of the rice production comes from this land. For this reason, the Institute is intensifying its research work with upland rice production, concentrating on problems of weed control, breeding drought-resistant varieties and studying the moisture variations of upland soils under natural rainfall conditions. Although it is doubtful that a rice variety will ever be developed with the drought tolerance of a sorghum plant for example, the chances of making a substantial improvement seem great enough to justify intensifying the research effort.

It is estimated that about 50% of the rice land in South and Southeast Asia is devoted to rainfed paddy (bunded but unirrigated). The critics of the Green Revolution have stated that the high-yielding varieties and the increased inputs that accompany them can be used profitably by only 10% of the farmers — those who operate farms in fully irrigated districts. Intensified research is needed on rainfed farms. There is reason to believe that they too can benefit substantially, although the risk is greater. A new and expanded research effort is now in progress in the Philippines to explore the problem fully, conducting field trials and obtaining data from groups of farmers living in carefully selected non-irrigated areas.

The Institute has shown that rice varieties vary in their photosynthetic rates by about 100%. High priority is being given to exploring this fact to the fullest degree and eventually to determining to what extent this character can be added to already improved varieties, and thus further increase yield potential.

The need to make a thorough analysis of the economic and social impact of the Green Revolution is closely related to the study of farm enterprises in non-irrigated rice-growing areas. Policy-makers in the developing countries read articles in the mass media as well as in various journals pointing out possible harmful consequences of the use of modern technology. These articles, although interesting reading, are often not based on fact. There is insufficient information available to support definitive statements on the subject. Carefully planned studies should be initiated in six to eight of the major rice-producing countries of tropical and subtropical Asia to assess the situation in the countryside. Answers should be obtained to such questions as: Which farmers are adopting the new varieties and what are their effects on farm incomes and net profits? If farmers adopt the new varieties, are they using additional inputs? If the adoption of the new practices is profitable, what are people doing with the extra money? Are their farms large or small? Are they irrigated or rainfed?

One area of research which has not yet been mentioned in this paper but which is an important item for future agricultural development is that of working out

cropping systems for the most profitable use of farm land in the tropics during the twelve months of the year that are uniquely available at those latitudes for crop production. It is important that intensive research be undertaken in different climatic environments to determine the best crops and the varieties and general management practices to be employed in year-round farming.

In my opinion, the most important procedure in organising research programmes in the developing countries is analysing the problems in a given situation and then directing the research toward their solution. At the IRRI we decided at the outset that the low rice yields in the tropics were the most serious problem affecting the well-being of the rural people so we set out to apply scientific principles to its solution.

Further analysis seemed to indicate that poor plant type and its consequential lodging when fertiliser was applied were the largest contributors to low yields. Of next importance was insect and disease control as well as soil and water management and weed control.

All of these factors received priority attention. As one serious problem after another is settled (though most biological problems are never permanently settled) the emphasis is shifted to solving other problems that are either less urgent or that have occurred more recently.

Agricultural problems in the less-developed countries will be ever-changing and research must be operated to give maximum freedom for the individual scientist to exercise his imagination and intuition within the framework of the overall objective of the programme.

The International Maize and Wheat Improvement Centre

N. E. BORLAUG

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I am very glad to be here today to participate in this conference. Referring to the Nobel Peace Prize, as far as I am concerned, this is an award given to agricultural science. I happen to be but one of the members of the research team on wheat improvement and it was in this part of the world that our most outstanding progress was made. We all know that no one person can get a programme such as the 'Green Revolution' moving. It is the collective effort of many scientists in many countries, together with many government officials and thousands of small farmers who have made it possible.

I have been asked to say a few words about CIMMYT and how it works with maize and wheat research programmes in different parts of the world. This international organisation was an outgrowth of the cooperative agricultural research programmes between the Mexican Ministry of Agriculture and the Rockefeller Foundation started in 1943. In certain respects the present organisational structure for agricultural research in Mexico evolved from this cooperative programme. In the years since CIMMYT was organised in 1964 we have continued to work hand in glove with the Mexican Ministry of Agriculture, using their national programme as a base of operation and working on their governmental experiment stations, with the exception of certain tracts of land that are used exclusively for the maize research of the International Centre.

RELATIONS WITH NATIONAL PROGRAMMES

I think there is a certain amount of concern in some countries of the world that the international centres are designed to take over the functions of national research programmes. This can never be so. The main effort in all countries must be the national programme and ours is really supplementary, to help in whatever way possible to strengthen the national programmes. We try to do this in several ways. First of all, we try to maintain a broad gene pool or collection of plant germplasm and varieties. These materials are sent to cooperating countries where they can be reselected or used in breeding programmes. Secondly, we function in a training capacity, in giving practical experience and training to young scientists from developing countries. In recent years we have also had a number of post-doctorate students who spend six months or a year to gain practical experience in our research programmes.

WHEAT RESEARCH

Now speaking specifically about the different kinds of projects of CIMMYT, I would like to point out that in the case of the wheat programme we have worked for about twenty-seven years. During this time we have collected and tested the best wheat varieties from the main spring wheat growing regions of the world. These varieties, for example, represent the typical strains of Canada, U.S.A., Mexico, Colombia, Argentina, Brazil, India, Pakistan, Egypt and so on — virtually all of the important wheat producing countries. The more promising wheats are grown in small plots in Mexico, made up into uniform sets of varieties and sent out to collaborators in different countries of the world. The data is channelled back to the headquarters at CIMMYT and compiled into an annual report or summary record. The report is distributed as promptly as possible to all the collaborators. In this way we obtain in one year's time a tremendous amount of data, not only on the yield of different varieties under different conditions but also on disease reactions, insect pests and sometimes on the quality of the varieties under a range of conditions.

Special Trials

It was through these types of tests that we first identified the wide adaptation of some of the Mexican varieties. Even prior to 1963, when we began to test some of these varieties in India in collaboration with the Indian Agricultural Research Institute, we had found that they were widely adapted throughout Latin America and North America.

In recent years we have added a similar type of uniform nursery for screening varieties for rust resistance. The varieties introduced so far have been resistant to the current races of rust but we know that adaptations in the organism may tend to change this.

We have a third type of screening nursery — what I call 'genetic soup' — from the breeding programme in Mexico. We include lines or varieties from the breeding nursery that are more or less uniform, show promise of yielding ability, with good grain quality, adequate cooking properties and good disease resistance. We have made up about 150 of these lines into special sets or nurseries which are sent to different collaborators around the world. We get back considerable data from these trials and many of the lines have shown promise in various countries. The collaborators are, of course, perfectly free to make selection from these materials if they seem suited to local conditions. A number of selections have already been made from these materials in different countries of the world.

Triticale

We have been working for the last six years to develop what we call *Triticale*. This is a man-made species, derived from a cross between *Triticum* and *Secale*, with the chromosome numbers doubled. We are interested in this particular cross at the present time because of nutritional values that we have not been able to find in wheat.

With limited feeding experiments in collaboration with Michigan State University we have identified several lines of exceptional nutritive value. We hope to be able to develop a variety which will also be high-yielding, as high-yielding as the best wheat if not better.

MAIZE RESEARCH

In the maize programme of CIMMYT, breeding lines or materials have been sent out as 'uniform tests' to collaborators in different parts of the world only in the last two years. Prior to that our scientists worked in different countries but there were no coordinated, uniform trials. These are now under way and we also hope to set up a germplasm screening nursery in which lines or selected populations will be sent out for examination under a wide range of conditions by collaborators in different maize growing countries of the world.

Nutritive Quality of Maize

A large part of the total effort in the maize programme is directed toward development of synthetic varieties, and in the last 2 or 3 years emphasis has been placed on high nutritive value, the 'Opaque — 2' type of nutritive value. The 'Opaque — 2' or floury-grained maize was found to have substantially higher lysine content than normal maize in studies conducted at Purdue University about six years ago. Since that time maize breeders in many parts of the world have been attempting to incorporate this high lysine quality into commercial maize varieties and hybrids. The potential benefits are very great. When Opaque — 2 maize is fed to white rats or to young piglets they grow at twice the normal rate as compared to animals fed the ordinary corn or maize When fed to children in advanced stages of calcium and protein starvation these children recovered spectacularly in about 8 weeks from their severe protein deficiency. This could be most important for the small-holder farmer who produces most of his family food requirements from his plot of land. Unfortunately, associated with the high nutritive Opaque — 2 gene, in the early hybrids and varieties, was a reduction in yield of about 10-12 per cent. Also, the grains are very soft and subject to severe attack by weevils and by ear-worms. However, during the last two years the maize research team in Mexico has succeeded in combining the nutritive quality with the yielding capacity of the best hybrids or synthetics, and also in correcting the softness of the grain. We have high hopes for producing a variety of maize which can yield with the best varieties available at the present time and also have a built-in nutritional advantage.

In the programme of maize improvement in Mexico, major emphasis is on synthetic varieties rather than hybrids. This recognises that the vast numbers of small farmers, especially in the North Central Region of Mexico, the Central American Highlands, West Indies and South America will not be in a position to buy hybrid seed each year in the foreseeable future. Consequently, it is more practicable to produce a high yielding synthetic variety that can be grown, harvested, and regrown without additional cost.

The Puebla Project

There is one pilot project which is a sort of sideline to the national programme of maize improvement in Mexico. This is an extension programme carried out in an area of relatively low rainfall that is exclusively maize producing. The farms are very small, most of them from 1 to 2 hectares, some of them less than one. They have had no benefit whatsoever from the new technology developed in Mexico and despite the fact that the know-how was available it had not been applied until two years ago. This special project was organised with the assistance of CIMMYT, working with the state of Pueblo and the Mexican Ministry of Agriculture. When the project was set up fertilizers were made available at the right time and of the right choice. The same was true of seed. Technical assis-

tance was given through demonstrations for the first year and then later actually working with the farmer. This has been spectacularly effective.

The project was started with a few dozen farmers, then went to a couple of hundred and now the large number is still growing rapidly. It is hoped that the pilot project can serve as a pattern for many other countries in Latin America where small farm sizes prevail. One of the unique features about the project is the good supply of credit for fertilizers, insecticides and weedicides — better than I have seen in any other part of the world.

TRAINING PROGRAMMES

In the past eight or nine years we have had about 175 young plant scientists from many countries spend 9 months to one year with us for practical field and laboratory training in the wheat programme. The maize programme also has its training component, of a similar nature, but the number trained up to now has been considerably less than in the case of wheat.

A limited number of staff members are assigned from or through CIMMYT to the countries where they can furnish guidance to the local programme. For example, from our CIMMYT programme we have assigned 4 staff persons in Morocco. This project is supported jointly by the USAID. In Tunisia there are 5 staff members in the joint understanding between the government of Tunisia, the Ford Foundation and the USAID.

FUNDS

The financial support for CIMMYT comes from the Ford Foundation, Rockefeller Foundation, USAID and United Nations Development Programme. The budget has been approved to receive some assistance also from the Canadian International Assistance Programme and the Inter-American Development Bank.

In closing, I would emphasise again that we do not intend for CIMMYT to take the place of national programmes. We hope to assist, through our training programmes and in other ways, those countries who are trying to launch or strengthen their national programmes for wheat and maize research. The International scope of uniform trials in different parts of the world, furnishing extensive data concerning adaptation, yields, disease and pest resistance should accelerate the development and use of modern technology for food production in all countries where wheat and maize are grown.

Cooperative Agricultural Research Programmes Between Countries with Similar Ecological Conditions

R. DEVRED

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The development of agricultural research and the improvement of cooperation and coordination of technical and financial aid in this field are problems of primary importance for agricultural development. Agricultural progress achieved in the more advanced countries has been obtained by continuing efforts in research and its application. A similar approach must be adapted by Governments of developing countries and supported by the technical assistance agencies helping them.

Developing countries, increasingly aware of the importance of research, are making valuable efforts to increase their scientific development. Owing to the large number of problems, however, it becomes increasingly more difficult for the research services to provide answers to all the inquiries raised.

The research undertaken and the technical assistance provided to research are both of considerable volume. It appears, however, that efforts made and the aid given do not cover sufficiently the fields involved. As a general statement it can be said that the varied research institutions and sources of assistance are insufficiently coordinated and that where coordination does exist it is usually established *during* the implementation of a programme or project by which time it is often too late to avoid duplication.

Nevertheless, there is a certain amount of experience in inter-governmental cooperation on regional projects and forms of liaison between different sources of technical aid in joint projects and sub-contracts which could provide a basis for closer cooperation in the future.

MAJOR PROBLEMS

The development of agricultural research is facing two main problems. One is concerned with availability of trained and experienced manpower and the other with the organisation and implementation of research programmes, including measures for ensuring that the results of research reach the field services in a form for practical use.

Qualified Manpower

Lack of qualified personnel is one of the major obstacles to research development. Even if funds and material allocated to research were tripled there still are not enough research workers available. With the increasing number of new states, demographic expansion, progress in science and technology, the development of research organisations and the competition to provide or receive aid and assistance, there has been a considerable increase in the number of projects and amount of technical assistance aid in various fields during the last five years. But to date an effective pattern of cooperation and coordination has not been established.

Financial and physical aspects (infrastructure) appear to be the other main barriers to the expansion of research activity, but it is mainly the lack of qualified personnel which limits its development. It is much easier to build and equip a research station than to find the necessary research staff. The demand for qualified research workers far surpasses the available support, particularly for those possessing tropical research experience.

Research workers who are capable of integrating several scientific disciplines, of comprehending technical as well as social and economic aspects of a research project, and who are interested in not only making new discoveries but also in their practical application, are particularly difficult to find. It is this type of research worker, possessing a wide range of experience, who is best suited to agricultural research programmes in developing countries.

Organisation and Implementation of Research Programmes

In organising and implementing research programmes, the need for an interdisciplinary approach and to relate research to the requirements of agricultural development plans are factors of prime importance in improving methods of cooperation.

Much of the agricultural research in developing countries does not fully reflect the multi-disciplinary nature of the problems involved. Development projects are often embarked upon without the necessary background technical, economic, social, organisational and institutional studies having been carried out. In other cases, studies and surveys already completed and published are ignored.

There is a pressing need to avoid competition and duplication through closer cooperation between developing countries, between developing and developed countries, and between bilateral, multilateral and international aid to agricultural research.

Some countries eagerly accept any offer of technical assistance even if it does not conform to priority needs of the country. Agricultural research in developing countries should be more concerned with the solution of their most urgent problems which are important to national and regional * development plans.

There are numerous studies, inquiries or pre-investment surveys which end up in the archives; far too much research stops at its publication; and enormous numbers of small specialised projects are carried out in isolation in too many so-

* For the purpose of agricultural research on an ecological basis the word 'regional' means a group of countries with similar agricultural problems.

called research stations conducted by one research worker only. Multipurpose projects, led by teams of research workers at multi-disciplinary research centres which also take account of problems involved in the application of research results, are to be found in limited numbers.

Political boundaries in Asia today are rarely related to ecological regions. One ecological zone will extend over several countries. However, as basic agricultural problems of a given ecological zone are similar, it seems highly desirable that regional cooperation in research be established on an ecological basis.

IMPROVING COOPERATION AND RESEARCH EFFICIENCY

Many measures can be taken to increase the efficiency of agricultural research but the first should be to make better use of trained and experienced personnel already available and to reorganise existing activities, as much as possible, in the form of multi-disciplinary projects at national institutes and as part of regional research programmes through inter-governmental agreements. Even without increasing funds and personnel presently available, it should be possible in this way to double or even treble the effectiveness of research and assistance provided.

Scientific and technical research in agriculture is expensive and requires highly trained and skilled personnel and costly field and laboratory equipment. The developing countries cannot afford to duplicate or repeat research already conducted elsewhere unless it is required for local adaptation. To a lesser degree this is also true for industrialised countries which are urged to increase their contribution to external bilateral or multilateral aid programmes, when it might be more logical to begin by ensuring better coordination and thus avoid costly and unprofitable competition. It is well known that cooperation and coordination raise many institutional, organisational, financial and political difficulties. It is believed that some of these difficulties can be overcome by an exchange of views between all interested parties.

The proposed solution for strengthening agricultural research and intensifying methods of cooperation is to establish a *Regional Agricultural Research Programme* in each of the major ecological zones, supported by bilateral and multilateral assistance as a framework for inter-governmental action. The desired goals would be:

(1) To organise research according to ecology, since most agricultural problems of an applied biological nature are more likely to be the same between countries having similar environmental conditions.

(2) To approach agricultural research problems on a multi-disciplinary basis and within their whole ecological area.

(3) To encourage development of research projects for which implementation would be shared by the existing research institutes in the countries of the ecological zone involved.

(4) To stimulate cooperation in research through closer working relationships between countries, institutions and individuals having similar scientific interests and carrying out research activities on the same problems.

(5) To conduct cooperative research, regional in scope and applicability, on problems of increasing the quantity and quality of food and agricultural production according to their order of priority.

(6) To facilitate cooperation in research among universities and research institutions between developed and developing countries, through engagement of the scientific staff in joint projects and the organisation of meetings, seminars, etc. on scientific and technical subjects pertinent to these projects.

(7) To develop and maintain intensive exchange of agricultural research information and to facilitate the shifting of scientific staff throughout the zone to give research workers opportunities to become better acquainted so as to extend their knowledge and experience beyond the boundaries of their research station area.

(8) To concentrate a portion of the resources devoted to agricultural research on key topics selected on the basis of regional priorities, to speed up development of new knowledge and the arrangements for transfer, adaptation and application of research results.

(9) To focus attention of the international scientific community, research institutions, scientific associations and other organisations on specific requirements of fundamental and applied research for the developing countries.

(10) To stimulate and promote cooperation in implementation of research by encouraging the establishment of partnership agreements and the pairing of research institutions.

(11) To make optimum use of and to strengthen existing national research institutions with a view to building up within the ecological zones concerned, a network of multi-disciplinary agricultural research stations.

(12) To avoid, as far as possible, unnecessary duplication and unprofitable competition in agricultural research, particularly for those research activities to be performed within the regional framework of ecological zones.

The interdependent nature of agricultural research problems in many Asian countries is well known. Ecological zone research programming is therefore an effective and rational way of isolating and selecting research priorities of the greatest mutual concern. Joint facilities, research implementation and results would be shared, thus achieving maximum effectiveness and economy. The solution of major agricultural problems is equally essential to all communities living in the same environmental conditions, whatsoever may be the pattern of their political, administrative or institutional structure.

Many research activities are already covered by national programmes or regional projects. Since the proposed regional programme aims to avoid wasteful dissipated efforts, the main objective of conferences on an ecological basis must be to indicate priority fields in which research should be intensified. It is particularly relevant to include in such a regional programme those priority problems to be studied in the entire ecological area, or which require standardised methods of investigation. A regional programme should be started on a modest scale rather than be an enterprise which is too heavy and complex and which will never supply expected results in time.

The implementation of a regional programme should be flexible, open to various kinds of cooperation and permit use of different ways and means to achieve its objectives. One of the more forceful justifications for this concept lies in the strengthening of existing national bodies as multi-disciplinary research institutions

able to work on both national and regional programmes. It must be recognised as a basic principle that the ultimate goal of foreign assistance is to help developing countries achieve 'self-sustaining' development through their own local institutions.

Although much research on problems of the developing countries is still going on in foreign institutions, these activities should progressively be shifted to local agricultural research institutions. Better coordination and cooperation of external aid efforts, organised within the framework of regional programmes, should make it possible to build up gradually a strong network of multi-disciplinary national research institutions.

Regional institutions — legally recognised as international and autonomous, created and provided with long-term financial support by private and philanthropic foundations or multilateral schemes of wealthy nations — would enormously facilitate the implementation of such programmes, particularly in the early stage of development. Such initiative should be strongly encouraged, on the understanding that those providing funds state their intention to continue financing these institutions over long-term periods.

At the present stage of development of research in most of the emerging countries, the establishment of regional institutes jointly financed by several developing countries is not a workable proposition. Developing countries are generally unwilling and unable to commit themselves to long-term financing for regional research institutes sited in a single country. Individual countries, despite high cost in financial and human resources, prefer to have their own national research institutions well established before contributing to regional institutes, the programmes of which are inevitably beyond their immediate control.

The establishment of regional research programmes on an ecological zone basis, to strengthen exchange of information and promote coordinated action for a limited number of common problems, will include technical meetings to deal with each of the priority problems selected. These meetings will bring together the interested parties to make a complete inventory of results acquired, evaluate the results, determine their practical application and decide on further research to be pursued.

After some years of cooperative working experience on a few regional research problems, the regional research programme could be enlarged progressively. It might well be that, in the future, regional teams of research workers would work together in national institutes. In a later stage, regional institutes could be set up in each ecological zone. The point to emphasise is that the final establishment of such jointly-financed regional institutes would be the *culmination* of a long period of cooperation, rather than a starting point for cooperation. Before proposing the establishment of regional institutes to be jointly financed by several countries, national institutions should first be developed to serve the implementation of national programmes.

The implementation of a regional research programme to be shared by several national research institutes and stations, and supported by various sources of external aid, would both strengthen national research programmes and facilitate joint action. This concept of organising research need not affect any government prerogatives nor any bilateral or multilateral technical assistance arrangements within countries. It should help to make better use of assistance by overcoming the shortage of manpower and avoiding unnecessary duplication.

The establishment of a regional research programme would promote closer cooperation between countries and increase the effective contribution of external aid. All research services of developing countries are in need of greater funds and Governments are unable to satisfy these needs in view of demands from the many other sectors of national development. External aid is therefore necessary to research. It would be easier to organise under the regional programmes.

A regional research programme must aim to use to their full extent the available national resources in multi-disciplinary activities complementing each other. Technical meetings, when preparing detailed work plans for selected topics of the regional programme, should suggest the fundamental studies and the basic research to be carried out to back up applied regional research programmes. This long-term and highly specialised research could be carried out initially by research institutions in the developed countries and by universities.

The concept of organising agricultural research on an ecological basis has many other advantages if applied on a world-wide scale. A world plan of action for the application of science and technology for development, recommended by the Advisory Committee of the Economic and Social Council of the United Nations, must be organised on a regional programme basis. In the fields of agriculture and renewable natural resources, the way in which problems should be solved depends largely on the prevailing environmental conditions in which they occur. Although the continents of Africa, Latin America and Asia are diverse in themselves, in the field of agriculture, research and applied knowledge are more similar between homologous ecological zones across these continents, than within a continent itself.

There is no doubt that research stations in the semi-arid zones of Asia have much more of an interest in establishing working relationships with research stations located in similar semi-arid conditions in Australia, Latin America, and in parts of Africa than with other stations sited in completely different environments. It is also true that results acquired in research stations in the wet monsoon zones of Asia are likely to be more useful to their counterpart ecological zones in Latin America and in Africa than to the neighbouring semi-arid zones of Asia.

Ecological principles which form the basis of agricultural practice were used intuitively by farmers and scientists alike a long time before the word 'ecology' came into use*. The landscape, vegetation, flora, fauna, type of crop farming, etc., in a given geographical region provide the true image of the combined effect of environmental factors. There is a great diversity of climate, environment and form of agriculture throughout the world, but the understanding of the evaluation of environments and biological processes allows the discovery of ecological affinities between very distant geographical areas. The survey of agro-ecoclimatic analogue areas throughout the main world ecological zones can make a definite contribution to the development of international relationships in agriculture and particularly in organisation of agricultural research. The establishment of closer cooperation, or even a simple information link, between similar ecological areas may lead to sayings in time, effort and cost. It may also bring about a more rational and wider utilisation of scientists' contributions and a more intensive exchange of mutual experience and information between those who are faced with similar difficulties and problems.

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*Ernest Haeckel, 1866.

An agro-climatology survey has just been initiated in the Philippines and Malaysia through a joint FAO/UNESCO/WMO action. When completed, this could be used as a background study for a first approximation of similar surveys in the counterpart homologues in the rest of Asia and other parts of the tropics.

The introduction of agro-ecoclimatic analogue data in directories of agricultural research stations and in catalogues of agricultural research programmes and results prepared with electronic computers would facilitate enormously the exchange of information and international cooperation in all scientific and technical fields of agricultural research development.

The establishment of agricultural research programmes on an ecological basis, with a standard system for cataloguing research programmes and results by electronic computers, and the study of agro-ecoclimatic analogues, would promote inter-country cooperation, widen the use of science's contribution to development and rationalise agricultural research organisation on a world-wide basis.

We all know very well the difficulties to overcome when dealing with cooperation between individuals, institutions or states. In science and technology, however, no country is able to fend for itself. It is our duty, and in our interest, to seek ways and means to better understand and cooperate with each other.

Part IV

National Agronomic Research Programmes

The Field Research Centre

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Asian countries faced with the urgent need for more effective agricultural development programmes are realising the need for providing a progressive technology for their agricultural sectors. A combination of limiting factors has, in many instances, caused this technological goal to be elusive. There is a vital need for providing both facilities and an operational framework whereby scarce scientific manpower in the agricultural sciences can be utilised with maximum efficiency. The creation of top quality, functional in-country research centres is an answer to many of these problems. This paper will offer suggestions as to how these centres might be realised.

THE PARTICULAR NEEDS OF THAILAND

Corn production in Thailand increased from 13,000 metric tonnes in 1950 to 1,218,000 metric tonnes in 1965 (3). This increase was accomplished through expansion of a single variety onto newly developed lands. Yields per hectare were relatively static. Technology was largely imported, with some adaptive innovations to Thai conditions. Sorghum also offered possibilities for adding flexibility to upland cropping systems and for extending feed-grain production to additional areas.

Following this rise in importance of corn and sorghum, a need was felt for establishing a more intensified research programme for development of technology and a programme for promotion of adoption of these developments. The staff for acceleration of the research was limited but a small group of people was available in the Department of Agriculture of the Ministry of Agriculture. The potential contribution to development by staff of Kasetsart University was restricted by their heavy commitment to teaching. Lack of adequate research facilities was also a serious problem. A concentration of effort to obtain greater output from the manpower, budget and facilities available was necessary.

The National Corn and Sorghum Programme, founded in 1966 as a co-operative effort between Kasetsart University, the Ministry of Agriculture and the Rockefeller Foundation has contributed to this objective. The goals are to increase the production of corn and sorghum through a sustained flow of new technology.

The plan includes an expansion of research capability through training of personnel at all levels and the construction of facilities. While the programme is not unique in its organisation, we feel that its approach, its implementation, and particularly its use of a research centre offer suggestions for solutions to chronic problems of developing agricultural systems.**

ORIGIN OF THE THAILAND NATIONAL CORN AND SORGHUM CENTRE

The development of the National Centre began immediately following the initial agreement between Kasetsart University and the Ministry of Agriculture. The site was Farm Suwan, a student training farm owned and operated by Kasetsart University, 150 kilometers northeast of Bangkok at an altitude of 300 meters in a corn and sorghum growing area. The objectives of the centre were: (1) to serve as a national research centre where concentration of effort would make possible development of adequate facilities for the conduct of high quality research; (2) to serve as a focal point in the programme in bringing together the agencies involved in a coordinated development drive; (3) to function as a training centre for university undergraduate and graduate students as well as for Ministry of Agriculture personnel. Therefore, major emphasis during the initial five-year period has been directed toward the development of facilities and services at the centre.

The centre was to continue under Kasetsart University ownership and operation, administered through a farm operations committee appointed by the Rector. Staffing at the centre was from both the University and Ministry. The farm administration personnel, project coordinator for the University and research technicians from both the University and Ministry constitute the resident staff.

GUIDELINES FOR STATION DEVELOPMENT

Objective development of good research facilities is an extremely complex procedure, attested to by the stark fact that of the hundreds of research stations in Asia, only a handful can be rated as adequate for conducting a wide range of in-depth research. This lack of field facilities has been emphasised by Moseman (1). There is, furthermore, an almost complete lack of understanding as to what constitutes a good field research facility.

The purpose of the greatest portion of crop field research in Asia is the development and selection of varieties, the measurement of interactions between these varieties and all aspects of their environment, and fitting these varieties into economical management systems. To accomplish these goals it is absolutely essential that precision measurements of crop response under uniform conditions in the field be made and that such measurements can be repeated. In assessing the role of environment, control over a wide range of variables is necessary. It should be emphasised that we are discussing field facilities and not laboratory requirements. The latter are more easily satisfied and are, in general, more adequate throughout the region.

It might be useful at this point to consider what a good national field station is not. It is not necessarily (and not usually) a vast complex of expensive buildings, paved roads, houses and laboratory facilities. It is not necessarily (and not usually) an artistic layout of fields and facilities designed to impress the casual visitor or members of a ministry of finance. There are examples of such stations in Asia whose aesthetic appeal outweighs their usefulness. The *research needs* of the utilising agencies should dictate the design of facilities and services.

** For a more complete outline of the coordinated, crop-oriented research approach see Welsch and Sprague (4).

Initial Physical Plant

The specific needs of a station may vary with country and location but the pattern of development remains basically the same. The selection and initial development of the physical plant is extremely important. To illustrate this point, we will use Farm Suwan in Thailand as an example. The site was selected because of its proximity to the corn and sorghum growing areas. The land area was adequate and the soil uniform and suitable. It may be desirable to have available uniform areas of different soil types, but when these soil differences exist in co-mingled patterns within experimental fields, the conduct of precision experiments becomes impossible. Station development began in 1966 with the conversion of a few existing dormitories and buildings into an initial physical plant structure. Maximum emphasis during 1966 and 1967 was placed on making field conditions adequate for research. Fields were laid out and cleared, roads outlined and the first stages of an irrigation system built. This second phase was the most critical for station development.

It was essential that all other station activities be designed around the field research facility; in other words, the field design and layout came *first*, with buildings and other physical needs fitted into the field design. In the development of many stations, unfortunately, dwellings and offices occupy choice sites and research fields are fitted around them. As a general rule, critical research cannot be carried out within about 50 meters of dwellings with their normal occupancy of families, pets, etc. Experience has shown that a very firm stand is required to prevent encroachment of buildings, roads, electrical lines and other facilities on research fields. It is essential to keep in mind the primary goal of the station: field research. The development pattern thus requires that research people, and field scientists in particular, serve prominently on station planning and development committees.

*Field Facilities**

Once fields are delineated the task of improving soil uniformity begins. This is a continuing requirement demanding the utmost diligence in management. A certain amount of land is needed for testing varieties or practices under uniform conditions, where measured differences may be small. This uniformity can only be developed and maintained by excluding those variables which contribute lasting effects to field variability. In some cases it may be possible to show that residual differences from such treatments cannot be measured statistically; however, these small differences contribute to field variability and often have a major effect on the precision of subsequent tests. At Farm Suwan, a land area totalling 20 hectares was set aside to serve this need for maximum uniformity. The research group decides each season how this land will be utilised. The plots are designed to utilise the entire field areas and alleys are placed in the same location each season. Fertiliser and other chemical treatments are uniformly applied to each field and accurate records are kept for each treatment.

Separate areas, with appropriate management systems, must be established for those experiments involving variables with persistent effects such as herbicides, fertilisers, residue management, planting dates, multiple cropping sequences or perennial plantings. To minimise the time over which these areas would be unsuited for further research, constructive plans must be made and implemented for restoring uniformity following such experiments.

Certain basic rules of management must be followed for all research areas. Mechanical operations such as land preparation must be held to a minimum. No

* The importance of proper field conditions for experimental use is discussed in Salmon and Hanson (2)

vehicle should be permitted on the fields unless it is engaged in a mechanical operation with the land or crop. Adequate provision for drainage is necessary to prevent runoff water from moving from field to field. Trees along field borders which contribute to the aesthetic atmosphere offer severe competition to adjacent crops and interfere with the efficient manoeuvring of field equipment. These and other landscape plantings should be removed. This careful management is extremely difficult to achieve and in many cases research people themselves do not recognise the need for treating research fields as 'sacred ground'. Farm operations people are not typically research orientated. It should be stressed that this management is not a costly luxury, but rather is a necessary and critical part of station operations. Until it is realised that such practices as routing roads or pasturing animals on research fields can do more damage in a few days than can be corrected in many years, facilities for precision research will continue to be unavailable.

The following is an illustration of good field management resulting in better uniformity for testing of corn and sorghum at Farm Suwan during the development period. The coefficients of variability for all 4-replication randomised complete block variety trials having equal plot size were averaged within years.

CORN YIELD TRIALS

Year	Number of Trials	Average C.V. (%)	Lowest C.V.
1967	4	15.6	13.5
1968	4	13.1	11.5
1969	6	11.5	10.6
1970	4	11.9	7.5

SORGHUM YIELD TRIALS (18 entries per trial)

Year	Number of Trials	Average C.V. (%)
1967	4	26.0
1968	9	28.6
1969	10	18.3
1970	9	11.6

This reduction in uncontrolled variability has made possible the undertaking of new lines of research where individual differences are small but which become significant when included in a variety management package.

Service Staff

Along with the moulding of adequate field facilities comes the development of a mission-oriented field staff. This involves the recruiting and training of people in field operations at all levels. It can readily be demonstrated that mechanisation of research vastly improves precision, but this mechanisation imposes even greater requirements on the training of field staff. A single tractor operator skilled in work-

ing research fields can make the difference between excellent or average trials which may determine success or failure in critical measurements in the research plots. In developing countries these skills are largely unavailable, and the selection and perfection of skilled workers require enormous time and patience. This phase of development is not accomplished solely through short-term training or brief apprenticeships, although these may help. The training of a good irrigator may require several years. It must be recognised that skilled farm operations people, from the management to the general labour level, are as vital a part of the research team as the senior scientist himself. They should be proud of their contribution to the output of the station and should command respect up and down the line. It is sad commentary that in most countries farm operations people are underpaid and not generally recognised for their skills.

Training in Station Management and Operation

Those who have worked in developing areas know well the problems of finding management and administrative personnel for supervising the creation and improvement of research facilities. It is important that these people be research oriented. Yet a person trained for research may not be adequately prepared for this development process. In the course of a student's graduate programme he is unlikely to be motivated to learn about station operation and management. Unfortunately, in most graduate institutions in developed countries, the infrastructure for research is taken for granted by the student. Furthermore, little opportunity is offered for even the interested graduate student to become acquainted with station logistics and management. Problems of procurement of supplies and equipment, machinery operation and repair, physical plant maintenance, personnel management and budget preparation remain a mystery. The Asian student who receives his training in agricultural engineering usually will have no background (and probably little interest) in agronomy or in field research. This lack of field management personnel is a major deficiency in Asia. Concentration of effort in training such people, whether on a national or international level, will pay handsome dividends to the research systems.

Completion of the Physical Plant

The final stage in station development is the completion of service facilities. The research needs must be carefully assessed and facilities completed to accommodate these needs. Continued effort is required to insure that development proceeds in that order. Quite often, for instance, the electric power organisation may dictate the power supplies for the centre and its facilities without having the slightest knowledge of the research or operational demands. A confounding factor also is the inexperience of research people in determining their own support needs.

An additional problem in station development is the termination of additional major construction once research needs are satisfied. The tendency seems to be to channel development money to successful projects, but 'over-development' can well ruin the station. Too many people, too many houses or too large a physical plant will detract from station usefulness to the research worker and also greatly increase unit costs of research operation.

CONTRIBUTION OF THE CENTRE

Development of Technology

The National Centre at Farm Suwan is now functioning in developing technology. Coordination across agency lines is achieved by bringing together scientists

from the different cooperating organisations. It is being demonstrated that the results of coordinated effort by the 17 research projects utilising Farm Suwan facilities is far greater than would be possible by independent activities.

An example of progress through this cooperation is shown in the *Appendix*. The new sorghum lines which were developed at the Centre are now being tested. They outyielded the local variety in nationwide station testing in 1970 by 67%; at Farm Suwan where disease incidence is high the advantage over the local variety was 300%. This disease-resistance developed at the centre no doubt contributed to more uniform performance in nationwide tests.

As a part of the development effort, animal nutrition studies have shown 25 – 30% increases in feed value over the local variety. These advances have been rapid because of simultaneous developments by research teams in the areas of breeding, pathology, entomology, soils, agronomy, nutrition and regional testing. Many of these advances are now starting through the channels of demonstration and extension, where they will multiply the effect of acreage expansion in the years prior to the increased emphasis on research.

University Development

The availability of a first class research centre and the increased competence in research of University staff members has strengthened the graduate programme. The increasing research capability within the University is providing opportunity for graduate students to receive high quality research training and meaningful participation in technological development by working with scientists on real problems facing Thai agriculture. This capability is achieving international recognition to the extent where graduate students from institutions outside of Thailand are conducting graduate research at the Centre under the auspices of the Kasetsart graduate school. Within the framework of the University, undergraduate students are exposed to modern agriculture and the development of technology, both through the experience of participating staff members and by direct contact during student training programmes at the centre.

Interagency Coordination

The Centre, by serving as a nucleus for corn and sorghum work, facilitates coordination of the participating government agencies. No governmental reorganisation has been necessary. The Ministry of Agriculture and Kasetsart University are both contributing in their areas of greatest strength through working agreements at the field level.

International Relations

Communication is a vital part of a productive agricultural research programme. The basic form of exchange of information is through formal publications. At the operational level, however, contacts through correspondence and visits are of great importance to professional development in a dynamic field such as agriculture. Continuing dialogue among staff members helps to generate ideas and diffuse information on technologies and techniques. The research centre provides an intellectual climate for such exchange.

The Centre also serves as a focus for receiving information from research outside the programme, especially from abroad. The development of the National Centre has generated enough attention so that visiting scientists, interested in corn

and sorghum work in Thailand, include a visit to Farm Suwan in their itinerary. These visits bring a wealth of information to the Centre. In return, information about the Centre and the research results are carried to other parts of the world. This 'export' also leads to a feed-back through receipt of publications, letters and further visits.

The Centre serves as a site for evaluation of introduced germ plasm for possible adaptation to Thailand conditions and for distribution of Thai materials to outside agencies. The exchange of corn material is greatly accelerated by the Inter-Asian Corn Programme (IACP), whose headquarters are located in Thailand in cooperation with the National Corn and Sorghum Programme, with corn improvement programmes in other Asian countries, and with CIMMYT. Success in these exchanges is facilitated by the attitude of the Thai government in expediting the issuance of visas to visiting scientists and in orderly movement of seeds through quarantine procedures.

This national dedication to international cooperation is also important in the International Training activity of the IACP. Extension and research workers from Asian programmes are brought to Farm Suwan for training in crop production technologies and in research and demonstration techniques. The sponsorship of trainees is shared among various national agencies and international aid-giving organisations.

SUMMARY

The ideas presented in this paper were not meant to be original. Rather, an attempt was made to stress the fact that well developed, functional in-country research centres are vital to national research systems. They servé a multi-faceted role in development programmes. One of our aims has been to point out the complexities of station development and management. The lack of available expertise in this area emphasises the need for greater attention to these problems within Asia.

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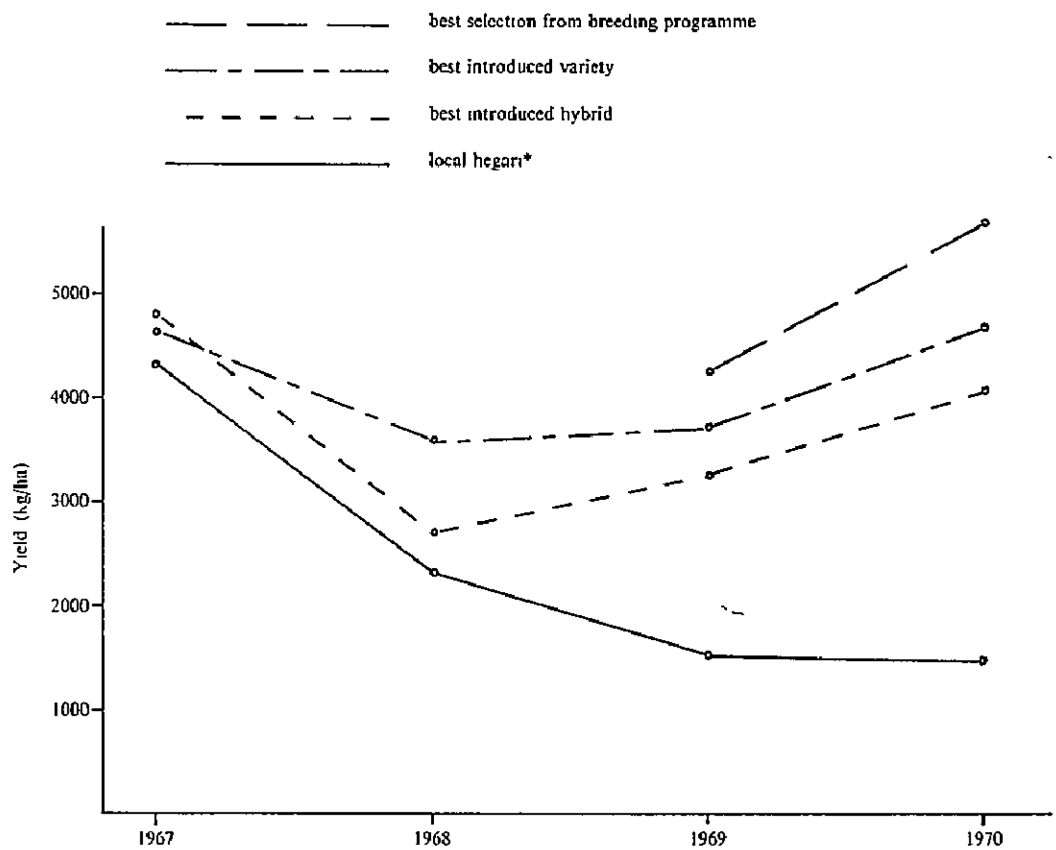
* The importance of proper field conditions for experimental use is discussed in Salmon and Hanson (2)

**For a more complete outline of the coordinated, crop-oriented research approach see Welsch and Sprague (4).

SORGHUM YIELDS AT FARM SUWAN, 1967–1970 (WITHOUT IRRIGATION)



* Reduced yields, 1969 and 1970, caused by increased disease attacks.

Research to Guide Diversification

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Taiwan is located on the edge of the continental shelf, about 150 km off the south-eastern coast of the Chinese mainland. Its total area is 35,960 sq. km (13,886 sq. miles). About two-thirds of the island is covered by the central mountain range extending from north to south. The agricultural land which is 30% of the total area is mostly in the western part of the island. The agricultural land limitation and population pressure have posed great difficulties in agricultural development. The government not only has to provide sufficient food for the ever-increasing population, but also must produce more foreign-exchange from crops for export. Fortunately, it has been possibly not only to produce enough food, but also to expand production of some new crops to the extent that Taiwan has become a leading exporting country.

The success in agricultural development can be attributed to several factors. By far the most important is research and extension. Scientists in Taiwan pay great attention to development of new farming methods and techniques which are well disseminated by the Farmers' Associations. The other major factor for the success of Taiwan's agricultural growth is the well planned and coordinated agricultural development programmes of the government.

This paper presents only a few of the more important features in crop diversification which have resulted from agricultural research.

THE MULTIPLE CROPPING SYSTEM

One of the distinctive features in the nation's agricultural development is the intensive multiple-cropping system which allows the succesive growing of two or more crops on the same piece of land in a year. This diversification and intensification of land use is the result of research to design cropping systems for sub-tropical and tropical conditions. Taiwan enjoys the high temperature and abundant solar radiation essential for crop growth all year round. The intensive agricultural systems include the conventional two rice crops and often one or more additional crops each year. The crop index in Taiwan is 190.0(1966). This figure indicates that on the average there are almost two crops grown on the arable land during the year. The multiple cropping system is practiced either in paddy areas or in the uplands although the latter are of relatively minor importance.

ECONOMIC IMPORTANCE OF DIVERSIFICATION

The multiple cropping system contributes a great deal to the agricultural economy in Taiwan. In *Table 1* it is indicated that all wheat, rapeseed and flax, 96.9% of the tobacco, 76.5% of the soybeans, 43% of the vegetables and 36.5% of the corn are produced under this system. The lands operated under the multiple cropping system are also much more profitable in terms of net cash returns than those in the two-rice-crop system *(Table 2)*. In the case of vegetables and tobacco, the net return is doubled. Even rapeseed, the least profitable crop, gives a quarter more return than two rice crops.

TABLE 1. THE ACREAGE OF VARIOUS CROPS UNDER THE MULTIPLE CROPPING SYSTEM IN TAIWAN, 1969

Crop	Total Acreage, ha	Acreage Under Multiple Cropping, ha	%
Vegetables	133,594	57,334	42.9
Soybeans	45,277	34,608	76.5
Sweet potato	233,804	41,916	17.9
Tobacco	11,952	11,585	96.9
Corn	19,265	7,032	36.5
Wheat	4,660	4,660	100
Flax	3,256	3,256	100
Rapeseed	2,227	2,227	100
Sugarcane	96,779	8,486	8.8

Source: 1969 Taiwan Agricultural Yearbook

TABLE 2. NET RETURN OF VARIOUS CROPPING SYSTEMS IN TAIWAN, (NT$/HECTARE)

Cropping Pattern	Gross Return	Cost of Production	Net Return	Index
Rice-rice	27,058	15,438	11,620	100.0
Rice-rice-rapeseed	36,388	21,832	14,556	125.3
Rice-rice-sweet potato	36,848	21,088	15,760	135.6
Rice-rice-soybean	34,819	18,532	16,287	140.2
Rice-rice-wheat	39,968	23,417	16,551	142.4
Rice-rice-vegetable	42,868	24,736	18,132	156.0
Rice-rice-tobacco	71,622	48,626	22,996	197.9
Rice-rice-2 vegetables	50,005	26,072	23,933	206.0

Source: 'Report on Economic Survey of Land Utilisation and Crop Production in Taiwan' Sp. Report, No. 42, 1965.JCRR.

MULTIPLE CROPPING PATTERNS IN PADDY FIELD

Farming practice in Taiwan is, in general, a two-rice-crop pattern. There is a time space of 40–60 days between the first and second rice crops and 90–120 days from the second rice crop to the first crop the following year. Thus, one or more additional crops can be fitted into a multiple cropping pattern. The additional crop added to the two rice crops may either be 1) a winter crop planted after the second rice crop, 2) a summer crop planted between the first and second rice crops, or 3) a combination of winter and summer crops to form a more complicated pattern.

The winter crops are sweet potato, tobacco, corn, soybean, wheat, flax, rapeseed, pea and other vegetables. The summer crops may be sweet potato, jute, vegetables, melons, etc., depending on such factors as water resources, soil conditions, labour supply and the marketing of the crop. The various cropping combinations are shown in the *Appendix*. The following are typical examples of the various cropping patterns.

Three-Crop Patterns

Tobacco

In central and southern Taiwan, tobacco is grown as a winter crop. The seedlings, grown in a separate plant bed by seeding in late August to early September, are transplanted at 35–40 days after seeding into the paddy field about two weeks before harvesting the second rice crop.

One row of tobacco is planted in every fourth row of rice, with one tobacco plant between every two rice plants in the row, so that the tobacco is spaced at 50 × 100 cm. Right after the rice harvest, the tobacco is fertilised and cultivated.

Since the rice crop is harvested earlier and the winter-month temperature is higher in southern Taiwan, tobacco is generally planted after harvesting the second rice crop in that area, and about the same time as it is interplanted with rice in central Taiwan.

Sweet potato

The growing period of sweet potato as a winter crop in Taiwan is 5–6 months. In the multiple cropping system, sweet potato cuttings are planted in every fourth row of rice at about 5–6 weeks prior to harvesting the second rice crop, to lengthen the growing period of sweet potato by about 1–1½ months. This crop can be harvested in February and the field is then ready for transplanting the first rice crop.

Sweet potato may also be used as a summer crop, grown between two rice crops, with a growing period of only about 40–50 days. The total growing period, including the interplanting, is less than three months. The sweet potato is not grown for tuber, but for vines as green feed for livestock. The interplanting method does not differ from that of the winter crop and both patterns are extensively adopted in central Taiwan.

Corn

Corn is planted in October, about 2–3 weeks before harvesting the second rice crop, in every third row of rice with the corn plants spaced at 30 cm in the row. Cultivation and fertilisation are done immediately after the rice harvest. This crop is grown either for seed or for table use.

Soybeans

In southern Taiwan soybean is the major crop. Soybeans are seeded in or near the rice stubble at 3–4 seeds per hill immediately after harvesting the second rice crop and without special land preparation. Only irrigation and fertilisation are done and there is virtually no cultivation. This type of planting not only saves labour but also reserves soil moisture for seed germination and early growth of the soybean. The crop is harvested within 90–100 days, just before transplanting the first rice crop. In areas where water is limited, a sweet potato-rice-soybean pattern is practised.

Vegetables

Vegetable crops such as Irish potato, carrot and tomato, with a growing period of 90–100 days, can be grown after the second rice crop. Alternatively, Chinese cabbage or peas are grown and harvested within 60 days and the field is then fallowed. Vegetables also fit well as a summer crop between the first and second rice crops.

Melons

Muskmelon, pickling cucumber and watermelon can be grown between the first and second crops of rice by transplanting the seedlings into the paddy field 25 days before harvesting the first rice crop. Melons and cucumber are usually harvested 60–70 days after transplanting.

Jute

Jute, a summer crop, requires 100 days from seeding to harvest. It is relay-interplanted in the paddy field two weeks before harvesting the first rice crop, using seedlings raised in a plant bed for about 30–40 days. The jute seedlings are transplanted in every second row of rice, with two plants between two rice plants in the row, so that the plant population is the same as that of rice. Two applications of fertilisers, and cultivations are made, one immediately after the first rice harvest and the other two weeks later. This pattern is only in central Taiwan on small farms with plenty of labour and skilled farming techniques.

In southern Taiwan, there is a time space of 70–80 days between the two rice crops so that jute may be transplanted after harvesting the first rice crop.

Four-Crop Patterns

A summer crop between two rice crops, and a winter crop after the second rice crop, constitutes a four-crop pattern in the paddy field. The farmers may choose the summer crops and winter crops to fit their own conditions. For this pattern, the rice variety for both crops must be early maturing. Other points to be considered are soil conditions and labour. The four-crop pattern is adopted in central Taiwan where water is usually not a limiting factor.

Five-Crop Patterns

The five-crop pattern is not a common practice in Taiwan. In this case, a summer crop between two rice crops, and two winter crops after the second rice crop, are grown. The two winter crops may be corn and vegetables or two crops of vegetables. The corn is used only for human consumption and not for seeds. The two vegetable crops may both be Irish potato, which is relay-interplanted in the paddy field 15–20 days prior to the rice harvest and can be harvested within 75 days, and any other vegetable crop which requires only 50–60 days. The total growing period for the two crops is approximately 120 days.

UPLAND MULTIPLE CROPPING PATTERNS

The upland multiple cropping patterns are not as common as those in the paddy areas because of the water shortage and relatively low soil fertility. The following are a few examples.

Watermelon-Soybean-Sweet Potato

The watermelon is transplanted in early March and harvested within 90–100 days. This is followed by one crop of soybeans which is also harvested within 90 days. Four to five weeks after planting the soybeans, sweet potato cuttings are interplanted with them. After the soybean harvest, the sweet potato is fertilised and cultivated.

Sorghum (Sesama)-Soybean-Wheat (sweet potato)

Sorghum is planted in late February or early March and harvested 120 days later. A crop of soybean is then planted and harvested within 90 days. In early October, a winter crop, either wheat or sweet potato is grown. This pattern differs from that in the paddy areas in that no interplanting is practiced.

RESEARCH CONTRIBUTING TO MULTIPLE CROPPING SYSTEMS

Research has played an important role in developing the multiple crop system which intensifies land use and increases total productivity. The contributing factors are:

Development of Early Maturing and Day Length Insensitive Varieties

The use of early maturing varieties, insensitive to day length, is essential in the multiple cropping system although they are usually lower in yield than normal maturing varieties. If the yield per day is considered, however, this disadvantage disappears completely. In the past, early maturity has been the main objective of crop breeding in Taiwan. New varieties were developed with a growth period of 90–120 days, depending on the crop. The new rice varieties, Taichung Nos. 180 and 186, for the second rice crop, are harvested 90–100 days after transplanting. The growth period of some crop varieties so far developed is 105–110 days for wheat, 90–100 days for soybean and 85–100 days for corn. Some vegetables need only 60 days from transplanting to harvest.

Relay-Interplanting

Relay-interplanting involves interplanting a crop in the paddy field prior to harvest of the rice crop; this enables the crop following the second rice crop to be started several weeks earlier and it thus has a much longer growing period. The crop has a normal growth and produces higher yields because of the relatively high temperature and more sunshine during the total growing period. However, the yield of the second rice crop may be reduced by 5–10% depending on the length of time the crop is interplanted. The relay-interplanting method is being constantly improved by studying the preferred timing of interplanting, spacing, fertilising, etc. Studies are carried out also on saving labour, more efficient use of fertilisers, and on minimising the rice yield reduction.

Control of Disease and Insect Pests

Intensive farming increases disease and insect control problems. Plant protection research is essential and control measures are developed either through

breeding resistant varieties or by using chemicals. The important disease resistant varieties for the multiple cropping system are TMV and powdery mildew resistant tobacco (Vam-Hicks and Vamfen -Hicks), downy mildew resistant corn (Tainan Nos. 8 and 9), rust resistant wheat (Taichung 33), soybean varieties (Tainung Nos. 3 and 4), and blast resistant rice (Chianung 242). Breeding rice varieties resistant to plant hoppers is underway. Fungicides and insecticides have also been commonly used to control various plant disease and insects.

Fertiliser Use

Soil fertility, another limiting factor for the multiple cropping system, has been extensively studied in Taiwan. Soil testing, together with fertiliser experiments, have enabled farmers to use fertilisers effectively to maintain soil productivity. Fertiliser supplies are made available to farmers at the right time but the present costs for fertilisers are still high.

The Exploitation of Water Resources

Water supply during the dry winter months in central and southern Taiwan is one of the determining factors for the adoption of multiple cropping. Great efforts made in the past to construct deep wells and dams were successful. Rotational irrigation programmes also have been developed for some areas, providing adequate water supply for the sequence of crops grown. Plant-water relationship studies and irrigation experiments on various crops such as rice, sweet potato, corn, soybean, tobacco, etc. provided the base for the rotation irrigation programme.

THE DEVELOPMENT OF EXPORT CROPS

In 1952, Taiwan's total agricultural export was only US$114 million of which sugar and rice accounted for 81.6%. However, the picture was completely changed in 1969. Sugar and rice accounted for only 14.8% of a total of US$343 million from

TABLE 3. EXPORT VALUE OF MAJOR AGRICULTURAL PRODUCTS (US$1,000)

Product	1952	1964	1969
Rice	23,240	18,030	4,239
Cane sugar	69,684	135,403	46,400
Banana	6,634	33,344	59,231
Pineapple (canned)	2,012	13,911	20,657
Mushroom (canned)	–	15,817	32,257
Asparagus (canned)	–	411	31,600
Fruit (fresh)	771	2,357	6,894
Fruit (processed)	184	6,180	11,283
Tea	5,745	8,426	13,555
Vegetables (fresh)	759	8,965	21,814
Others	5,177	62,954	94,714
Total	114,206	305,798	342,643

agricultural exports. This reflects the considerable amount of new agricultural products which were developed for export during the last two decades. The new agricultural exports now include mushrooms, asparagus, fresh and frozen vegetables, fresh and processed fruits, etc. *(Tables 3* and *4)*. This achievement is largely due to the careful planning and application of research findings.

TABLE 4. PRODUCTION AND ACREAGE OF MAJOR CROPS IN TAIWAN

Crop	Acreage (1,000 ha)		Production (M.T.)	
	1952	1969	1952	1969
Rice (brown)	787.5	786.6	1,570,115	2,321,634
Sugarcane	98.0	94.3	4,801,883	7,012,410
Sweet potato	233.5	233.8	2,090,463	3,701,769
Peanut	81.0	91.5	60,037	100,764
Soybean	24.3	45.3	14,627	67,111
Wheat	14.6	4.7	16,604	9,950
Corn	5.1	19.3	6,981	44,777
Tea	38.0	33.7	11,582	26,248
Banana	15.7	37.6	106,856	585,531
Pineapple	5.8	12.4	62,760	325,013
Citrus fruit	4.6	20.4	27,770	170,105
Asparagus	–	8.3	–	67,642

Pineapple

Taiwan is one of the world's more favourable areas for pineapple production. However, there was no appreciable amount of pineapple produced for export from 1945 to 1956 because of a variety of problems which have now been solved through the research programmes.

The control of pineapple wilt disease. No satisfactory control was established for the wilt disease until 1950 when it was found that it was transmitted by the mealy bug *(Dysmicoccus brevipes)* and was symbiotic with ants which promoted spread of mealy bugs in pineapple plantations. The mealy bug was brought under control by treating planting materials with Folidal E-605 and the ants were controlled by Aldrin. The control of the wilt disease encouraged farmers to grow more pineapples.

Closer spacing. Pineapples were previously grown at a density of 20,000 to 25,000 plants per hectare. The yield can be increased by as much as 48% in the first harvest and 14% in the second if the density is increased to 40,000–45,000 plants per hectare, with the same amount of fertilisers. The fruit size produced in the denser planting also is better suited for canning. The waste is 9% less than that of pineapples grown under wider spacing because of more uniform fruit size.

Improvement of pineapple varieties. The original pineapple variety was low yielding and non-uniform in size because it was a mixture of several strains. After several years of selection the Normal Smooth Cayanne was produced which was high yielding, of good quality and had uniform sized fruit which gave less canning waste.

Soil and water conservation. Pineapple plantations in Taiwan are mainly on the slopes or hilly land. Heavy erosion often occurs as a result of inadequate planting layout; this heavy cost in land productivity resulted in some land being abandoned. New soil and water conservation practices have done a great deal to help farmers improve their planting methods to maintain soil productivity. The most important change is the use of contour planting, with straw or plastic mulching.

Increased use and proper application of fertilisers. The rate and proportion of fertiliser application has been improved by an annual application of 8 gm N, 2 gm P_2O_5, and 8 gm K_2O per plant.

The adjustment of time of fruit setting. The harvesting of pineapple in Taiwan is during July and August. This large supply in a short period taxed the capacity of the canning factories and depressed prices and income. The excess caused great loss to the pineapple growers. The method developed for promoting flowering by treating the young bud with 50 cc of 0.5–1.% carbide solution or by two applications of 0.5–0.7 gm of carbide to the young pineapple bud at an interval of 3–5 days will promote 95% flowering 2–3 months earlier. The treatment is usually carried out in September and the fruit is ready for harvesting in May. This enables growers to produce pineapple at an earlier date and prolongs the processing period.

Mushroom

There was practically no mushroom production in Taiwan before 1953 because it was generally considered a temperate zone crop. The industry has developed so rapidly that Taiwan is now one of the leading mushroom exporters. Annual production in 1969 reached two million cases of canned mushroom valued at around US $32 million. This remarkable success is attributed to the following factors:

The use of synthetic compost. Mushroom is traditionally grown on horse manure in most mushroom producing countries. The development of synthetic compost for mushroom growing is the principal contributing factor for its production in Taiwan. This compost is composed of rice straw 100 kg, urea 1 kg, calcium superphosphate 3 kg, $(NH_4)_2SO_4$ 2 kg and $CaCO_3$ 2.5 kg.

The development of pure culture spawn. Mushroom spawn was often contaminated with other fungi or a mixture of inferior strains. The pure culture spawn produced by the Taiwan Agricultural Research Institute and distributed to the spawn plants by the Provincial Department of Agriculture and Forestry has resulted in a stable production because of its purity and high productivity.

The improvement of mushroom varieties. Mushroom is known to undergo genetic change because of the reproductive nature of the fungus. The improvement programme, financed by the JCRR and the Mushroom Research Fund, succeeded in developing large numbers of new strains which are vigorous, high yielding and possess excellent canning qualities. Particular success was also achieved in developing strains tolerant to the relatively high temperatures prevalent during the growing season under subtropical conditions.

Polyethylene lining of mushroom houses. The conventional rice straw and sugarcane leaf mushroom house is inadequate for pest control by fumigation or for

prevention of outside infection. Neither does it provide good heat insulation for keeping constant room temperatures. A close-type PE house was designed by lining the inner wall of the rice straw or sugarcane leaf house with polyethylene foam sheets and installing a ventilator. The mushroom yield in the PE house was 50% higher than that of the conventional rice straw house because the optimum temperature (65°F) and humidity (85–90%), required in certain periods of mushroom growth, could be properly maintained.

Production of granular spawn. The granular spawn is made of a well-decomposed compost with other ingredients such as grain hull powder, shell powder and starch mixed with water. It is equal to grain spawn but is much lower in cost. As compared with the usual compost spawn, the mycelial development after inoculation is very rapid and evenly distributed. The button stage appears earlier, resulting in a shorter period from inoculation to harvest; this, in turn, reduces the possible infestation of insects and diseases. Higher yield is also obtained when granular spawn is used.

Other economic factors:

a. The Mushroom growing is in winter — the slack farming season in Taiwan when labour shortage is not so acute.

b. Rice straw for synthetic compost and bamboo for mushroom houses are readily available throughout Taiwan.

c. The limited space required for mushroom growing does not compete for land with other food crops.

d. The coordination of the mushroom and pineapple production season makes maximum use of canning factory facilities.

Banana

Before 1958, banana production was limited. Research on physiology, post-harvest handling, fertilisers, pest control and variety selection were conducted by various organisations. However, due to lack of funds, the coordination and extension services were so inefficient that research results were not applied. During this period both planted acreage and yields increased only slightly. Research and extension were well coordinated after 1960, with the result that both the acreage and yields were substantially increased *(Table 4)* The most important contributing factors are summarised as follows:

The proper use of balanced compound fertilisers. It was found that potash and phosphorus, which had not been applied in appreciable amounts by growers, significantly affected the banana yield. Consequently, the 9–7–23 (for lowland) and 11–5.5–22 (for hillslopes) fertilisers were developed through research. The rate of application recommended was 2.0–2.5 kg per plant with 4–5 applications a year. It was also recommended that most of the fertilisers be applied from time of planting until two months before flowering.

The control of major pests and diseases. The corn borer *(Odoiporus longicollis)*, once a problem, is now satisfactorily controlled by timely trapping and large scale applications of pesticides. Mealy bugs and aphids, though of minor importance, were carriers of disease and are now well under control.

Sigatoka and bunchy top were the two most destructive diseases in Taiwan. Sigatoka disease was fairly well controlled by spraying mineral oil mixed with Dithane

M-45 ten times a year. The control of vector aphids did not effectively check the spread of bunchy top. An all out eradication treatment and replanting cut the loss down to 1–3%.

Closer spacing. Regular planting density used in Taiwan was 800–1,600 plants per ha, depending on slope or lowland plantings. Research findings indicated that a yield increase of 48–58% could be achieved at a planting density of 1,200–1,400 plants per ha for slopes, and 1,800–2,000 plants per ha on lowlands.

Irrigation, soil and water conservation. Irrigation in the winter dry season and drainage in the rainy season were essential for successful cropping. More irrigation facilities were installed and drainage systems on lowland were strengthened. The soil and water conservation projects implemented on sloping land also benefitted banana production.

Measures for minimising typhoon damage. Typhoons have been a great hazard to banana production in Taiwan. To minimise losses the erection of bamboo pole props and the growing of vegetative windbreaks were widely adopted.

Improvement of cultivation practices. Efforts have been made to improve various cultivation practices: (1) Mulching with straw and dried banana leaves to preserve soil moisture. (2) Removal of dried banana leaves as soon as possible to reduce the spread of Sigatoka disease.

Strengthening of extension programmes. Extension programmes have been greatly strengthened since 1963 so that information from research can be channelled to farmers through pamphlets, demonstrations, discussions and personal contacts.

Citrus

Taiwan is well suited for citrus growing. However, large scale production of quality citrus products has been achieved only in recent years; the total production was 170,105 M.T. and the export was valued at U.S. $3.7 million in 1969–70. Most of the fruit was shipped to Hongkong, Singapore, Ryukyu and the Philippines. The acreage harvested was 20,435 ha. in 1969–70, almost four times the amount fifteen years ago. The value of citrus fruits now ranks third among the fruits produced in Taiwan.

In quantity and economic value, the mandarin is the most important citrus fruit in Taiwan. Ponkan (*Citrus poonensis*, Hort, ex Tanaka) and Tonkan (*Citrus tankan*, Hayata) are the two leading varieties; both are loose-skinned and have excellent eating quality. Second in importance is the sweet orange (*Citrus sinensis*). The early maturing 'Sikan' and 'Golden Seal Orange' and the late maturing 'Valencia' are the three major varieties of sweet orange, while shaddock, lemon and others are of less economic value.

The rapid increase in citrus fruit production in recent decades was largely due to the larger acreage planted. The demand for large numbers of nursery trees stimulated the improvement of propagation techniques in citrus nurseries. The use of plastic sheets, cut into strips, and plastic tubes instead of muddy paste to protect the grafts resulted in a take of 90% or more. A new device for applying insecticides to control pests by painting systemic insecticides on the stem of the young trees, six inches above ground level, was developed successfully to control leaf miner and red spider. This device was not only easy and labour saving but also left beneficial insects unharmed.

Despite the control of diseases and pests by application of pesticides, the 'Tristeza' and 'Tristeza-like' decline diseases reduced yields. The 'Tristeza' virus disease is transmitted by aphids and can be controlled by using resistant rootstock. However, the similar 'Tristeza-like' decline was found to be caused by mycoplasma which is transmitted by Psylla *(Deaphorina citri*, Kuway). The rootstock presently used is susceptible to this disease. A search for resistant root stock has not been successful so far and the problem still remains to be solved.

Asparagus

Asparagus is another temperate zone crop that has been successfully grown in subtropical Taiwan in recent years. Asparagus production began in 1955 on a very small scale for supplying the tourist restaurants and U.S. military personnel. Later it was found that asparagus grew very well in the alkaline sandy soils of the coastal plains of southern Taiwan. Substantial increase in production began in 1963 when the canning industry was developed and canned asparagus went into the international market. The acreage grown reached 8,300 hectares in 1969 with an export value of over US$30 million. Asparagus now ranks second after the mushroom among the canned food exports.

The selection of varieties adapted to the warm climate and well drained fertile sandy soil is one of the most important contributing factors, along with improved cultivation methods. The practice especially adapted for the warm climate is to reserve some of the stems as mother stalks during the growing period so that the asparagus will not lose too many nutrients to support vigorous growth.

Onion

The onion is a long day plant and grows well in a cool dry climate. In the past, the high humidity and temperature in Taiwan was considered unsuitable for onion production. Attempts to grow onion in northern Taiwan before 1950 were unsuccessful. However, under JCRR supported projects, repeated trials of a number of introduced onion varieties produced two adaptable and high yielding selections (Texas Early Grano 502 and Excel Bermuda) which were identified in 1951 by the Taipei District Agricultural Improvement Station. It was also found that the cool dry winter season in southern Taiwan was especially suitable for growing these two varieties.

Successful onion production depends also on better cultivation practices. Close-spacing with density of 796,600 plants per ha yielded 50% more than the normal density of 307,600 plants per ha. The high planting density resulted in difficult and laborious weeding so the use of herbicides has become common practice.

By 1955 onion production was sufficient to meet domestic needs. By 1956, there was a surplus for export to Hongkong and countries in southeast Asia. Large quantities of onions have been exported to the Ryukyu Islands and Japan since 1962. The rapid increase in export was partly due to the early harvest of the Taiwan onion (February — April) which coincides with the high demand period in the international market. Production reached 31,000 M.T. in 1969 when the export value was US$1 million.

FUTURE PROSPECTS

Further progress in agricultural diversification in Taiwan will undoubtedly depend on how well we deal with some of the remaining major problems, none of which are unique to Taiwan.

The major problem that farmers face is the margin of profit which is gradually decreasing in recent years because of rising production costs. The increasing shortage of farm labour and rising wages are the most important. This is the result of rapid industrialisation which absorbs labour from the rural areas, with more attractive pay. The rising cost of fertilisers, farm supplies, materials and tools is another primary problem. As a result of such higher costs, the multiple cropping index in 1969 was slightly lowered to 184.3 as compared with the average of 188.0 in the past five years. Farmers are losing interest in farm investments and reducing food crop production in winter, leaving some of their land idle

The government, is aware of this and remedies are being made. The first is to lower the price of fertilisers. The other is an overall farm mechanisation project. Government is spending a total of NT$2 billion for these projects in the five year period beginning in 1970.

The average farm size is only one hectare in Taiwan and this seriously impedes implementation of farm mechanisation. The selection of suitable farm machines and acceptable cooperative farm operations are under investigation. Land consolidation programmes also will be further promoted and strengthened.

The effect of low market prices of certain food crops is serious, particularly so when soybean, maize and wheat import control is lifted. A heavy import duty on these food crops and the establishment of a price stabilising system will help to maintain a reasonable price and profit-margin for these crops.

The special crops for export are usually less affected by rising costs than are food crops because of the higher profit potentials in the international market. Some special crops may be further developed by increasing the acreage of more slopeland planting.

Knowledge and improved facilities for post-harvest handling techniques are urgently needed since heavy losses occur during transit and storage. On the average, 5–25% loss in fresh fruits and vegetables is common.

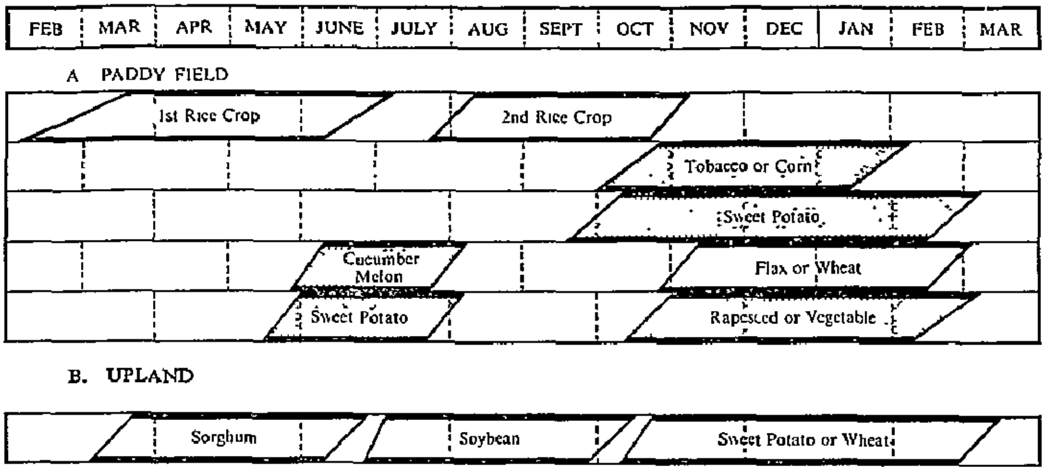
Improvement of marketing systems is also indispensable to help farmers keep a fair share of their profits while maintaining a reasonable market price for consumers. However, small farm size and the subsequent small-volume sale lots complicate the problem.

The government is also spending a considerable amount of money in strengthening various agricultural research projects to increase yields, improve product quality and to develop more mountain resources. It is our belief that if further progress is to be made research must be given first priority. 'Research with a mission' can be taken as a theme for further contributions of research to agricultural development.

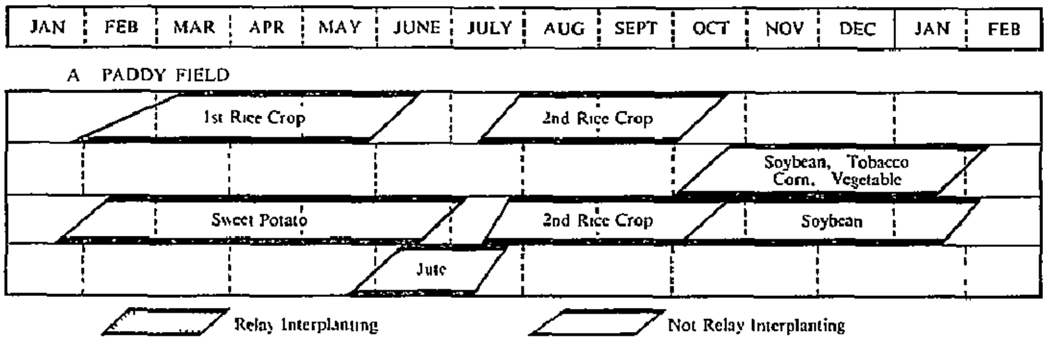
Any fruitful research programmes must be carried out by well-trained scientists. The shortage of qualified personnel and the proper training and retention of brilliant scientists has been one of the most serious handicaps in the nation's development in agriculture. Steps are being taken to improve salary scales for scientists and to improve their research environments.

MULTIPLE CROPPING PATTERNS IN TAIWAN

I CENTRAL TAIWAN



II. SOUTHERN TAIWAN



Soil Research Organisations in India

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Soil is the backbone of agriculture. In India, where agriculture is the predominant occupation of most of the people, soil research acquires added importance. Owing to diversity of climate, geology and the network of rivers and streams, there is a great variety of soils and a greater complexity of problems. The alluvial soils which predominate in the thickly populated and intensively cultivated areas add to the complexity and diversity of soil problems.

Soil research in India started with general agricultural research, in agricultural chemistry. Soil science as such did not get much attention in many states until 1947. Thus, modern soil research organisation is primarily a product of the post-Independence development. In the pre-Independence days, soil science as a part of agricultural chemistry was not given the attention it deserved; yet problems of soil fertility, soil survey — and even to a certain extent soil salinity, alkalinity and soil acidity— were getting attention from scientists from the beginning of this century because of their practical significance. Much greater attention was paid to soil science in the newly irrigated canal areas where soil survey, water quality, salinity and alkalinity problems were important. Soil fertility and fertiliser research also was considered of vital importance for increasing crop production.

In the pre-Independence era in almost all the Indian states, soil research was assigned to agricultural chemists, who were mostly physical, organic or inorganic chemists; some of them were also graduates in agriculture who had specialised in agricultural chemistry. Except for a few states such as Bombay (now Maharashtra), Punjab, Uttar Pradesh, Bihar and Madras (Tamil Nadu), soil science did not receive significant attention in the universities, in the state colleges of agriculture or state department of agriculture. However, in states where canal irrigation was important, soil research received due recognition and was very much intensified in the early 1930's.

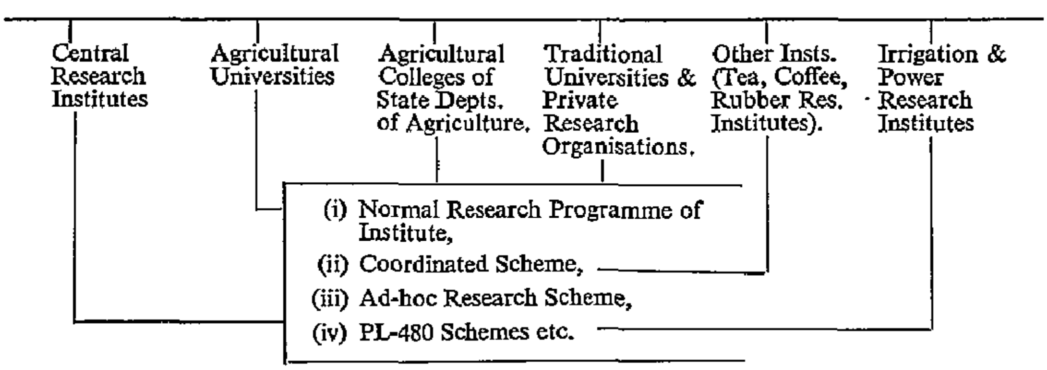
The Indian Agricultural Research Institute, formerly known as the Pusa Institute, had a Division of Agricultural Chemistry and Soil Science which did much pioneering work on fundamentals of soil chemistry. Likewise, in the Punjab, research in soil science was actively pursued in the Punjab Agricultural College at Lyallpur as well as in the Irrigation Research Institute at Lahore. Both of these institutions are now in Pakistan. The situations were similar at the Government Agricultural College, Kanpur in U.P., at Poona and Nagpur in Maharashtra, and at Coimbatore

in Tamil Nadu. The organisation of the Indian Council of Agricultural Research (then Imperial Council) in 1929 also gave support to research in soil science all over the country. Schemes on soil survey, nitrogen fixation, reclamation of saline alkali soils, dry farming, fertiliser research, etc., have received support from the Council over the years.

As mentioned earlier, the major change in organisation of soil research came in the post-Independence era. The interest in use of fertilisers, necessity of soil testing, increasing problems of soil fertility, soil chemistry and soil physics, quality of irrigation water and the growing interest in soil conservation, accelerated soil surveys, greater emphasis on irrigation projects, pre-irrigation and post-irrigation surveys all gave impetus to the organisation of soil research in India. In the last ten years, a number of agricultural universities have set up separate departments of soil science. In the agricnltural research institutes also soil science is receiving greater attention because of the numerous soil management problems of practical importance. The growing demand for fertilisers and the setting up of soil testing laboratories and fertiliser factories gave a real boost to soil science research organisations all over the country.

The Indian Council of Agricultural Research has played a major role in organising, sponsoring and coordinating soil research in the country. This is being done through its central research institutes, the state agricultural universities and the research institutes of the state departments of agriculture and traditional universities. The chart below shows the research organisational patterns:

SOIL RESEARCH ORGANISATIONS



ORGANISATION OF RESEARCH BY THE INDIAN COUNCIL OF AGRICULTURAL RESEARCH

The Indian Council of Agricultural Research, which was set up in 1929, is the apex organisation for agricultural research including animal sciences. It has helped initiate, strengthen and coordinate agricultural research in the country over the years. But after independence it was felt that the pattern of organisation was not adequate and suitable to meet the challenging needs of the times. Moreover, there were a number of commodity committees, on cotton, oilseed, coconut, sugarcane, tobacco, etc., which were not directly connected with the Indian Council of Agricultural Research. Thus, there were different patterns of organisation and channelling of funds for research.

A Joint Team of Indo-American experts appointed by the Government of India to review organisation of agricultural research and education in the country recommended that the Council be reorganised with a scientist as its Director General

and with four Deputy Directors General. This was done in 1966. The Review Team realised that soil science research required special emphasis. The position of Deputy Director General (Soil, Agronomy and Engineering) was created and, under his guidance, soils research in the country has been reorganised, energised and coordinated.

Besides administering, supervising and coordinating the research activities of its constituent Institutes, the Council also initiates, organises and coordinates research in soil, agronomy and related fields throughout the country. There are three types of research programmes:

(a) Research in the central research institutes of the I.C.A.R.

(b) Coordinated research

(c) Ad-hoc research.

Soil Research in Central Institutes

The premier institute of agricultural research in India is the Indian Agricultural Research Institute (IARI), New Delhi which has the oldest Division of Soil Science and Agricultural Chemistry. This Division has been in existence since the Institute was established in 1905. The Division has expanded, with a number of new divisions: (1) Agricultural Physics, (2) Microbiology, (3) Agricultural Chemicals, (4) Biochemistry and (5) The All-India Soil and Land Use Survey Division with its four regional centres at (a) Bangalore (red soil), (b) Nagpur (black soil), (c) Calcutta (laterite and coastal soil) and (d) New Delhi (alluvial region).

The Nuclear Research Laboratory, New Delhi also owes its origin to the Soil Division. The IARI has produced the majority of soil scientists occupying important positions in different universities, state departments, industry, etc.

Besides the IARI, there are a number of agricultural research institutes under the direct control of the Indian Council of Agricultural Research, which have divisions or sections for soil research. There are ten such institutes:

1. Central Arid Zone Research Institute, Jodhpur (Rajasthan).
2. Central Rice Research Institute, Cuttack (Orissa).
3. Central Plantation Crops Research Institute, Kassargod (Kerala).
4. Central Potato Research Institute, Simla (Himachal Pradesh).
5. Indian Sugarcane Research Institute, Lucknow (Uttar Pradesh).
6. Indian Jute Agricultural Research Institute, Barrackpore (West Bengal).
7. Central Tobacco Research Institute, Rajahmundry (Andhra Pradesh).
8. Central Tuber Crops Research Institute, Trivandrum (Kerala).
9. Indian Grassland & Forage Research Institute, Jhansi (Uttar Pradesh).
10. Central Horticulture Research Institute, Hassarghatta, Bangalore (Mysore State).

The soil research of these Institutes relates to the commodity of interest and also to general problems of soil science.

The Central Arid Zone Research Institute has a division for resource survey. It is also setting up another Division for soil-water-plant relationship studies. All of

these institutes, besides carrying out their specific programmes of research, also participate in the coordinated national programmes.

In addition to the foregoing Institutes, there is the Central Soil Salinity Research Institute, Karnal (Haryana) set up exclusively for research on soil salinity and allied problems.

Soil Conservation Research Centres

Realising the importance of soil conservation, the Government of India set up, in 1954, nine centres in different agro-climatic and soil regions of the country for soil conservation research, training and demonstration. These centres are being strengthened and reorganised under a Coordinator in the Fourth Five Year Plan. They are located at:

1. Dehra Dun (hilly area)
2. Chandigarh (sub-mountain area)
3. Bellary (black soil region)
4. Ootacumund (hill area of the Nilgiris)
5. Kota (ravine lands of the Chambal, Rajasthan)
6. Agra (ravine lands of Uttar Pradesh)
7. Vasad (ravine lands of Gujarat)
8. Ibrahim Patnam, Hyderabad (red soil)
9. Chhatra (Himalayan region) — (It has been transferred to the Department)

Besides these centres, one soil conservation centre at Hazaribagh (Bihar) is operating under the direct control of the Damodar Valley Corporation (DVC).

All these centres were under the Ministry of Food and Agriculture until 1967, when they were put under the ICAR. They are concerned with the development of techniques for soil and water conservation and for increasing production from rainfed areas. These centres are also actively involved in the Coordinated Scheme on Dry Land Agriculture of the ICAR.

Coordinated Research Projects

Coordinated research is generally multi-discipline and multi-locational. It is directed to the solution of pressing practical problems and makes use of facilities available in different agro-climatic and soil regions. The recurring expenses, which include staff salaries, contingencies, travel allowances, etc., are borne by the Indian Council of Agricultural Research. A leading scientist experienced in the chosen field is appointed as Project Coordinator. A team of specialists prepares the outline of the project and identifies the centres which should participate in it. Their report is carefully considered by the ICAR and the project is submitted to the Planning Commission and the Ministry of Finance. After it is finally approved, the ICAR implements it in collaboration with the Cooperating Units.

The annual workshop of the project/scheme, which is a business meeting of the scientists engaged in its implementation, reviews the programme and progress of the project. The Coordinator is responsible for ensuring the proper conduct and implementation of research programmes through the Cooperating Units and reports to the Deputy Director General of the ICAR.

The coordinated projects exclusively related to problems of soil science and agronomy are listed in Table 1.

TABLE 1. LIST OF ICAR PROJECTS/SCHEMES ON SOIL SCIENCE AND AGRONOMY

Scheme	No. of cooperating centres.
1. *Soil Productivity Research*	
(a) Coordinated scheme on micronutrients	8
(b) Coordinated scheme on soil structure	9
(c) Coordinated scheme on soil test-crop response correlation	12
(d) Coordinated scheme on organic matter decomposition	6
(e) All-India coordinated agronomic experiments scheme	44 centres and 50 districts
2. *Soil and Water Management Research*	
(a) Coordinated scheme for research on water management and salinity	16
(b) Coordinated scheme for research on cropping patterns and water management	10
3. *Dryland Agriculture*	
Coordinated scheme on research on dryland agriculture	24

Ad-hoc Research Schemes

These research schemes are of two types: (1) those financed by the ICAR out of cess funds, and (2) those financed out of PL-480 funds. This category of schemes is generally operated only at selected centres and they are run for short periods of usually three to five years. They cover basic research as well as applied research of local or regional interest. The programme and progress of the ad-hoc research schemes financed by the ICAR is examined by a panel of soil scientists and agronomists.

The PL-480 research projects are financed from the PL-480 funds. They are of mutual interest to Indian scientists and to the U.S. Department of Agriculture. There are very few PL-480 projects in soil science.

Research Fellowships

The Indian Council of Agricultural Research awards a number of research fellowships to meritorious students for M.Sc., Ph.D. and post-doctorate work in soil science as well as in other fields. The candidate is required to take up research on a project of mutual interest to the ICAR and the university.

Soil-testing Laboratories and Extension Work in Soil Science

With support from the Technical Cooperation Mission of the United States (now USAID), the Government of India set up 24 soil testing laboratories throughout the country in 1956. The number of these laboratories has increased over the years. More recently a number of laboratories have been set up by state governments, fertiliser manufacturers, etc. The total number of soil testing laboratories is 182 and their capacity for analysing soil samples and giving advice to farmers ranges from 10,000 to 30,000 each. The soil fertility specialist at the ICAR provides technical support to this programme and a soil fertility specialist in the Ministry of Food and Agriculture looks after the extension work in soil testing.

The soil scientists, besides their role in soil research and education, have a prominent part in extension also. Under the National Demonstration Project of the ICAR, 100 soil science subject-matter specialists have been appointed in 100 districts in the country to advise farmers on soil problems and balanced fertiliser use for increasing agricultural production.

Thus, the Indian Council of Agricultural Research has organised and co-ordinated a wide range of soil research projects throughout the country.

SOIL RESEARCH ORGANISATIONS IN THE STATES

Agricultural Universities

In the different states in India, soil research is organised in the agricultural universities or in agriculture colleges of the state departments of agriculture where there are no universities. The agricultural universities are autonomous organisations supported by the states and the ICAR. They collaborate with the ICAR in coordinated projects for which the entire funds are provided by the ICAR. They also carry out some ad-hoc and PL-480 research schemes in addition to their own research and educational activities. At present there are thirteen agricultural universities in India:

1. Andhra Pradesh Agricultural University, Rajendra Nagar, Hyderabad (Andhra Pradesh)
2. Assam Agricultural University, Jorhat (Assam)
3. Haryana Agricultural University, Hissar (Haryana)
4. Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur (Madhya Pradesh)
5. Kalyani University, Kalyani (West Bengal)
6. Mahatma Phule Krishi Vidyapeeth, Rahuri (Maharashtra)
7. Orissa University of Agriculture and Technology, Bhubaneswar (Orissa)
8. Punjab Agricultural University, Ludhiana (Punjab)
9. Punjabrao Deshmukh Krishi Vidaypeeth, Akola (Maharashtra)
10. Rajendra Prasad Krishi Vishwa Vidyalaya, Sabour (Bihar)
11. Udaipur University, Udaipur (Rajasthan)
12. University of Agriculture Sciences, Hebbal, Banglore (Mysore State)
13. Uttar Pradesh Agricultural University, Patnagar (Nainital, Uttar Pradesh)

Agricultural universities are also being set up in the states of Tamil Nadu, Gujarat, Kerala and as an 'agricultural complex' in the university in Himachal Pradesh. Every agricultural university has a department of soil science with a professor and head of department. In some agricultural universities there are more than one professor of soil science. In some cases, soil scientists engaged on specific research projects carry special designations as soil physicists, soil chemists, soil fertility specialists, soil microbiologists, soil extension specialists, etc.

The total number of soil scientists engaged in research, teaching and extension varies from state to state. The Punjab Agricultural University has over 150 soil scientists engaged in research, education and extension.

State Departments of Agriculture

The departments of agriculture of the states also employ soil scientists for work in soil fertility, soil conservation, soil surveys, etc. In states where there is no agricultural university, soil research is part of the overall programme of the agricultural colleges and is also spread over a number of regional research centres. In some states, the soil survey is in a separate organisation under the state department of agriculture. In a few states, there are soil survey organisations in the irrigation departments for survey work in irrigation project areas.

Soil Research in Traditional Universities

Besides the agricultural universities, some traditional multi-faculty universities have taken interest in soil research. A notable example is Calcutta University which has been doing research on clay minerology and other fundamental problems of soil chemistry. The Sheila Dhar Institute of Soil Science, Allahabad University, has engaged in research on soil fertility and related problems. The Punjab University, since pre-Independence, has maintained its interest in soil chemistry and soil physics research. The Annamali University is actively engaged in research on problems relating to soil microbiology. A few other traditional universities also have maintained their interest through ad-hoc research schemes financed by the Indian Council of Agricultural Research.

Research for Effective use of Land and Water Resources

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Research is the foundation of development of a country. The backwardness of many developing countries is caused by the inadequacy of agricultural research and educational programmes and lack of support by political and administrative bodies for the research to produce innovations. Agricultural technology is 'location specific' and, unlike other technologies, it cannot be transferred from one country to another without suitable testing, modification and adaptation to local conditions. The failure to realise this fact has led to many disappointing results. Another factor which has contributed to poor results in agriculture in developing countries has been the lopsided development of agricultural research over the years, as commodity oriented — particularly export commodity oriented — with utter neglect of research on soils and water, the two principal natural resources. Inadequate attention has been paid also to the development of an integrated technology for difficult farming systems.

In India there is growing concern about the lack of balance between the rate of population growth and agricultural production. The country is already cultivating about 46% of the total geographical area and has almost reached the physical frontiers of extension of cultivation. The only scope lies in increasing production per unit area per unit time. The potentials for this are very large as India's average crop yields are among the lowest in the world. National Demonstrations conducted with high yielding seeds and new technology have shown that from the same land one can produce on an average 4–6 times more and, in fact, the highest attainable potential is even 8–10 times *(Appendix I)* under irrigated conditions (Kanwar 1970). The country has nearly 80 million irrigated acres or one-fifth of the total irrigated area of the world. Abundance of sunshine is another gift of nature which can ensure cropping around the calendar. Thus the scope for increasing production under irrigated farming is vast, but the success lies in the development of suitable technology which is site specific and economically feasible. Water alone is not enough and miracle seeds do not produce miracles unless the right combination of factors such as fertilisers, soil management, water management and crop management practices interact (Kanwar 1969). The failure to realise this has led to many disappointing results *(Appendix II)*.

The most difficult problem is to increase production per unit area from non-irrigated or dry lands, which constitute 80 per cent of the cultivated area of the country. Unless production from these areas is improved, the overall average yield in the country will not meet future requirements. The widening gap in production

levels between farmers in irrigated and unirrigated areas has created an urgency for developing suitable technology for the latter areas. The Indian Council of Agricultural Research has developed a Coordinated Research Project on Dryland Agriculture which operates at 24 centres with the coordinating centre at Hyderabad. The project aims to develop soil, water and crop management techniques and improved cropping systems to efficiently utilise the natural rainfall. Canadian scientists are collaborating in this project under the bilateral programme between India and Canada. In view of the seriousness of the problem and its socio-economic and political consequences it is felt that an international research institute for dry land agriculture, developed on the same lines as the IRRI, is badly needed. India is ideally suited for the location of such an institute.

In the Regional Seminar on Soil Fertility and Soil Survey organised by the ICAR and the FAO at New Delhi last month, attention was focussed on soil fertility problems related to the green revolution. As a result of intensive cropping with high yielding seeds, a number of soil fertility problems have become evident. These will continue to grow in complexity as agricultural production levels rise. Intensive research is needed to solve problems of major and micro nutrients. Since such research is site specific a network of experiments has been created throughout the country.

The problems of pollution and residual and accumulative effects of modern agricultural technology are of widespread concern. The use of chemicals is indispensable for improving productivity and long-term studies are required to evolve rational uses of chemicals without irredeemable impairment of environments.

The efficient use of land requires adoption of suitable cropping patterns for different soils and climatic conditions to maximise production. The yields obtained by farmers under the national demonstrations programme conducted by research scientists in 100 districts on an intensive scale, and in other districts extensively, are shown in *Table 1*.

The droughts of recent years and the disparity in production of irrigated and unirrigated areas have led to intensive efforts to exploit underground and surface waters. According to Dr. Khosla (1970), an authority on irrigation in India, roughly 50% of the total water wealth of 1,350 million acre feet received in rainfall over the country can be utilised. Through the end of the Third Five Year Plan about 200 million acre feet has been exploited and 475 million acre feet is still available for future development through major, medium and minor irrigation works, including underground water exploitation. The effective use of water resource necessitates both basic and applied research on the rate of depletion and recuperation of water in the aquifers and on efficient water management. The low rate of growth in rice production has also focussed attention on water management research.

An efficient land and water use system also requires increased attention to mechanisation, both under irrigated and non-irrigated farming conditions. The small size of holdings and acute employment problems require a technology suited to Indian conditions. Projects have been planned to study the energy requirements of different cropping systems and to develop suitable machinery for different situations.

In view of the foregoing factors, the Indian Council of Agricultural Research has taken up intensive research on soil and water management problems through selected coordinated research projects.

TABLE 1. YIELD IN TONNES/HA/YEAR OF MULTIPLE CROPS UNDER NATIONAL DEMONSTRATION

Crop rotation	Average yield, tonnes/ha			Highest yield, tonnes/ha		
	67–68	68–69	69–70	67–68	68–69	69–70
Rice-rice	10.49	9.45	10.47	16.95 (A.P)	20.15 (Mysore)	17.80 (A.P)
Pearl Millet-wheat	7.96	7.70	7.23	15.01 (Punjab)	11.36 (Haryana)	10.31 (Gujarat)
Rice-wheat	9.03	9.67	9.35	15.62 (Delhi)	21.76 (Rajasthan)	14.27 (U.P)
Sorghum-wheat	6.48	8.19	8.04	12.10 (Mysore)	12.84 (Mysore)	12.58 (Mysore)
Rice-wheat corn/* rice-corn-rice**	10.67*	12.59*	–	16.48* (Delhi)	23.41** (Tamil Nadu)	–
Rice-rice-rice	13.33	15.49	13.7	18.08 (Tamil Nadu)	18.59 (Kerala)	17.99 (Kerala)
Jute-rice-wheat grain	9.97	10.30	10.12	14.63	14.10	15.82
fibre	2.13	2.14	1.31	1.23 (Orissa)	2.43 (Orissa)	1.62 (Orissa)

SOIL MANAGEMENT RESEARCH

The soil productivity research has the following coordinated projects, in which teams of scientists work together to develop suitable technology:

1. Coordinated agronomic trials.
2. Coordinated research on micro nutrients.
3. Coordinated research on soil test-crop correlation.
4. Coordinated research on soil structure.
5. Coordinated research on organic matter decomposition.
6. Long term experiments to monitor the changes in soil environments as a result of intensive modern agriculture.
7. National demonstrations.

Time does not permit discussion of details of these projects and I will only touch upon some of the more important problems and trends of research.

Major Nutrients

The Coordinated Agronomic Trials aim at development of location-specific technology to maximise production per unit area per unit time under different agro-climatic and soil conditions. A few thousand trials are conducted at 44 research centres and in 50 districts on cultivators' fields every year. These experiments have clearly demonstrated the importance of information from cultivators' fields to supple-

ment the result from research centres. The high yielding seeds give better response than local varieties, not only with high doses of fertilisers but also at low to moderate fertiliser application as shown in *Table 2* and *Appendix III.*

TABLE 2. RESPONSE PER UNIT OF N OF DIFFERENT VARIETIES OF CROPS (HIGH-YIELDING VERSUS LOCAL)

Crop	Dose of N, kg/hg.	Kg grain per Kg N	
		High-yielding variety	Local best variety
Rice	40	19.22	17.90
	80	16.53	13.64
	120	12.98	9.20
	160	11.73	7.89
Wheat	20	24.1	13.3
	40	20.2	10.4
	80	12.3	4.7
	100	18.4	1.8
Maize	45	22.0	16.0
	90	18.0	13.0
	135	16.0	11.0
	180	14.0	9.0
Bajra	40	14.8	7.0
	80	10.6	5.0
	120	9.5	5.6
	160	8.7	4.1

These trials have shown wide-spread deficiency of phosphorus, potash and zinc, in addition to universal deficiency of nitrogen. The response to fertilisers also varies with the nature of the soil and its nutrient level *(Appendix IV)*. Experiments are underway on multiple cropping, fertiliser requirements for targetted yields and on method and time of application of fertilisers. It is evident that without balanced use of fertilisers it is not possible to obtain high yields of crops, particularly in multiple cropping.

Micro nutrients

Exploitive agriculture leads to serious depletion of micro nutrients. Recent research in India has shown very wide-spread deficiency of zinc and significant responses to applications of zinc sulphate. In soils deficient in zinc, the full responses to NPK will not show up unless zinc is supplied.

There are interesting varietal differences in crop response to micro nutrient deficiencies and an intensive screening programme has been undertaken to categorise crop varieties according to 'susceptibility' to micro nutrients. Some of the high yielding varieties of wheat, rice, sorghum and maize are more susceptible to zinc deficiency than are others. On soils low in available zinc, the non-susceptible variety may not respond to application of zinc whereas the susceptible variety will not grow successfully unless zinc is applied.

The micro nutrient research has also led to interesting results on interactions of zinc and phosphates. In some soils, zinc deficiency becomes evident after heavy applications of phosphates due to the phosphate zinc interaction in the soil as well as in the plant. Applications of zinc show responses up to a certain critical limit, beyond which they depress yields (Kanwar 1970).

Multiple cropping with high yielding varieties and heavy doses of NPK are producing more wide-spread deficiency of micro nutrients. Farmers may obtain very high yields under multiple cropping for 2–3 years but zinc deficiency then becomes so acute as to cause virtual failure of the crop. Results from field experiments on cultivators' fields by the Punjab Agricultural University illustrating this point are shown in *Table 3*.

TABLE 3. YIELD OF WHEAT GRAIN (Q/HA.) DUE TO ZINC TREATMENT, 1969–70*

Treatment	Mohanpur	Gujjarwal	Chak Chela	Gurah
N P K	17.32	21.22	18.66	12.32
NPK + Zn 5 ppm (Soil Application)	30.33	26.51	24.39	19.65

Note: The NPK doses at Gurah were 160,80 and 40 kg/ha respectively; at other places as applied by the farmers.

* Annual Report 1969–70, Department of Soils, PAU, Ludhiana.

It is evident that when the target is 4–5 times more production the micro nutrient and even secondary nutrient depletion will increase more than in proportional amounts. A farmer producing 13.5 tonnes of wheat and rice per annum per hectare is removing annually 274, 312, 574, 17, 4290 and 1225 gm/ha of boron, copper, zinc, molybdenum, iron and manganese, respectively. Since the amount of available micro nutrients in the soil is only a few kg/ha, it can be appreciated that these must be replenished. Because of the antagonistic effect of micro nutrients, no 'shot-gun' method for correction of deficiencies by using ad-hoc mixtures of micro nutrients can produce satisfactory results. Micro nutrient problems will be increasingly serious and soil scientists, plant physiologists, agronomists, plant breeders and plant pathologists will be jointly concerned. In India there is evidence that many diseases of wheat and rice are due or related to nutritional disorders caused by micro nutrient imbalances.

Soil-Test, Crop-Response Correlations

The recent International Symposium on Soil Fertility Evaluation organised by the International Society of Soil Science, Indian Society of Soil Science, Indian Society of Agronomy and the Indian Council of Agricultural Research highlighted the problems and approaches to soil fertility evaluation. Intensive coordinated research has been undertaken on soil testing to predict fertiliser requirements. By use of a computer and multiple regression techniques fertiliser requirements can be calculated for a targetted yield. Efforts are being made to develop an integrated index of soil fertility.

For rice, contribution of N by the subsoil seems to be substantial. There is evidence that hexoamine for rice and amino nitrogen for wheat are more important than other forms of nitrogen.

Since fertilisers are very costly and the future of agriculture depends on them, improved techniques are needed to guide fertiliser recommendations. The farmer is interested in knowing not only what is deficient in his soil but also how much of a specific fertiliser should be used to achieve a particular yield level. Efforts to quantify this relationship are being made under the coordinated soil-testing scheme. In three field experiments with IR8 rice, the fertiliser requirements for target yields of 73.0,

75.0 and 91.0 quintals per hectare were calculated. The actual yields obtained by Ramamoorthy and his associates (1970) were 75.4, 77.0 and 96.4 quintals per hectare. Similar experience was gained on wheat.

Soil Structure

Improvement of the physical condition of the soil is necessary for increasing the efficiency of fertilisers, decreasing losses of nutrients and providing favourable environments for crop growth. Under multiple cropping systems, for crops such as wheat and rice which have divergent requirements for soil physical environments, suitable soil management systems must be evolved. Deep ploughing of soils with dense subsoils for wheat, and compaction of soils for paddy was found to be highly beneficial. Coordinated research is in progress to develop technology for improving soil structure.

RESEARCH ON WATER RESOURCES

It is a paradox that despite the fact that no agriculture is possible without water, this is one of the natural resources which has not been exploited fully and is used least efficiently. In India, where agriculture is subject to the vagaries of monsoon, hardly one-sixth of the total annual rainfall is now effectively utilised. There are two main problems, (1) the exploitation of untapped sources of water, surface as well as underground water, and (2) improved water management for improving efficiency per unit of irrigated water. Although huge sums of money have been invested to exploit the available water resources in the country, the management of water for agriculture has been seriously neglected. Because of poor water management practices poor returns have been realised from costly irrigation projects. The recent droughts and food shortages, and the introduction of high yielding seeds, have created an urgency for development of improved technology for water management.

The ICAR has initiated coordinated research projects on water management, has set up a Central Soil Salinity Research Institute at Karnal and a Water Technology Research Centre at the IARI. The water research projects involve participation by most of the agricultural universities and central and state institutes. They are:

1. Coordinated scheme for water management and salinity (15 centres).
2. Coordinated scheme for cropping pattern and water management (10 centres).
3. Coordinated research on engineering aspects of tubewells and ground water hydrology (5 centres).

It is also proposed to further strengthen research on water management in hilly areas, and on saline water. The main difficulty in these programmes is the dearth of scientists with experience in water management and inadequate facilities. The training programme has been stepped up with USAID assistance and with collaboration of the University of California at the Water Technology Centre at IARI.

Under the UNESCO programme, water management post-graduate teaching is being strengthened in some agricultural universities.

Some Trends of Research in Water Management

It is being increasingly realised that we must move from protective to productive irrigation. For maximising efficiency of water, high yielding seeds, balanced fertilisers, multiple cropping and suitable agronomic technology are essential. The real further breakthroughs in rice production will not be achieved unless water

management in rice culture is improved. In rice cultivation, about half the water is being lost in leaching. Similarly, due to poor water management 40 to 60% of the nitrogen applied as fertiliser is lost from use by the plant. Experiments have shown that submergence of rice fields with more than 5 cm of water is unnecessary. Where water is a limiting factor, irrigation at critical stages of growth is more efficient than throughout the growth period. In cereals generally, tiller initiation, pre-flowering, flowering and grain development are the most critical stages for irrigation. In the case of wheat, irrigation at crown root initiation and at ripening is very critical. Four irrigations at the critical periods of growth for wheat produced 41 per cent more yield than the same amount applied at the wrong time. Likewise, for paddy in the alluvial soils at Cuttack, irrigating when the soil just started cracking resulted in 3 times as much efficiency as with continuous irrigation. This is shown in *Table 4.*

TABLE 4. EFFECT OF DIFFERENT WATER MANAGEMENT PRACTICES ON RICE AT CUTTACK*

Treatments	Grain Yield, kg/ha	Water used,** mm/ha	Water use efficiency, kg/mm/ha	Water use index, % requirement of water under submergence condition
Weekly irrigated 8 cm depth	7966	1296	6.1	50.5
Alternate wetting and drying, 5 to 8 cm water applied at flowering	7780	1619	4.8	63.1
Alternate wetting and drying (alone).	7730	1287	6.6	50.2
Irrigation when soil just started cracking	7695	900	8.6	35.1
Continuous submergence	7550	2566	2.9	100.0
Irrigation when soil completely crusted	7126	423	16.8	16.5

* Chaudhury and Pandey, 1969.
** Includes rainfall received also.

There is a general notion that the high yielding varieties require more irrigation than local varieties but experiments have shown that this is not necessarily so. The high yielding varieties are more exacting with regard to timing of irrigation (than to total amount of water) and because of their high yields per unit area per unit time, they utilise water more efficiently than the low yielding traditional varieties.

Problems of water management in deteriorated soils, saline alkali soils and acid sulphate soils of the coastal areas are of a special nature. Great interest has developed recently in the use of saline water for irrigation. The use of nuclear energy for exploiting underground waters and for desalinisation of water is being seriously considered.

Future research must be directed more effectively to exploitation of the water potential in the country, its efficient utilisation and prevention of the consequence of poor water management on soils. In Asia, where rice is the predominant crop — and the most wasteful user of water — water management systems must receive more critical attention.

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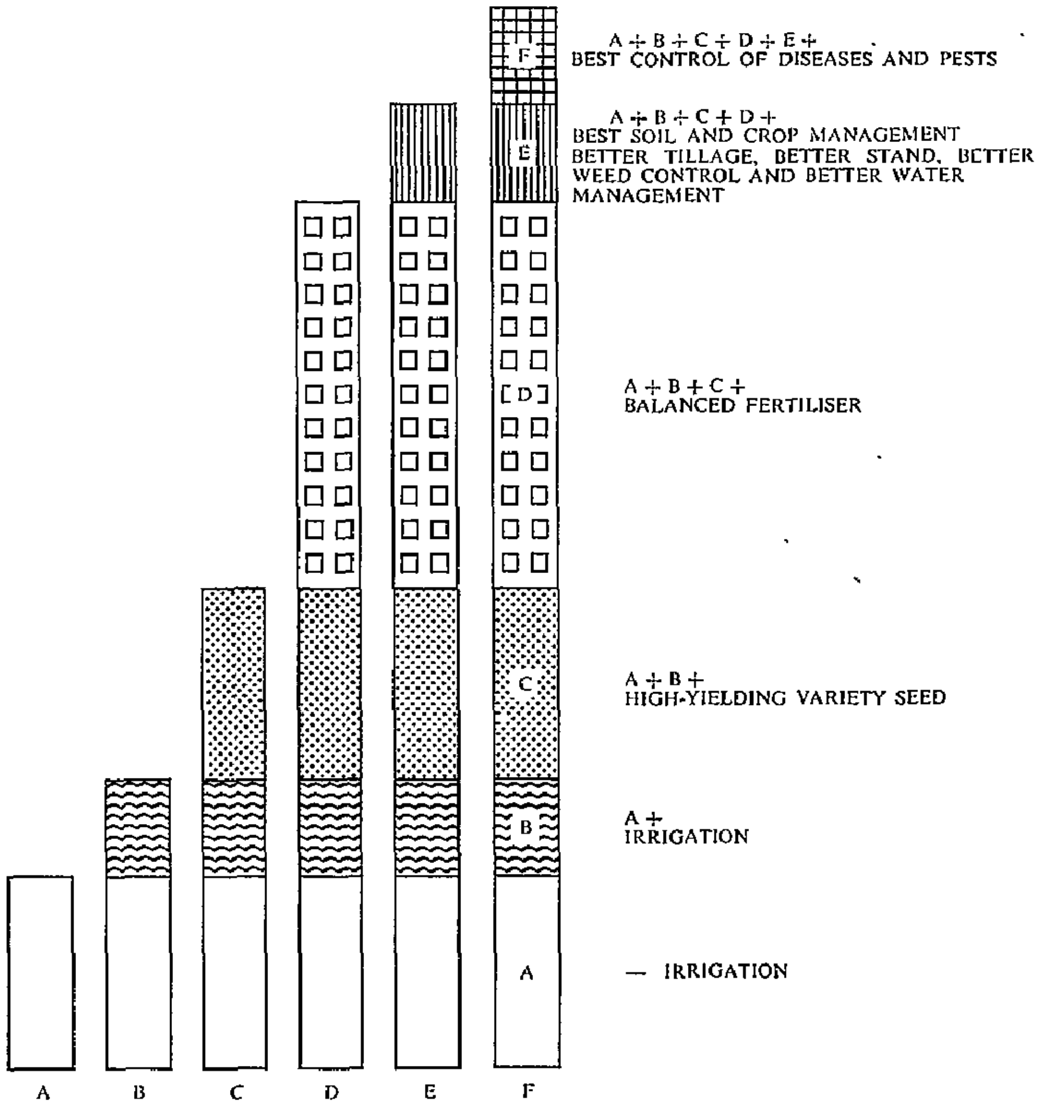
PRODUCTION POTENTIALS OBTAINED UNDER NATIONAL DEMONSTRATION 1965–69
(YIELD IN Q/HECTARE)

Crop	Average yield obtained under national demonstration					Highest yield obtained					Percent cases exceeding targets				
	1965–66	1966–67	1967–68	1968–69	1969–70	1965–66	1966–67	1967–68	1968–69	1969–70	1965–66	1966–67	1967–68	1968–69	1969–70
Paddy	41.95	47.95	53.34	59.46	55.37	59.40 (W.Bengal)	107.69 (Orissa)	110.50 (J & K)	152.89 (Rajasthan)	128.00 (J & K)	63	62	83	87	87
*Ratio	3.14	3.71	3.45	3.71	3.41										
Wheat	39.61	36.82	41.78	40.04	40.70	68.00 (Delhi)	84.00 (Delhi)	90.60 (Haryana)	102.00 (M.P.)	93.5 (M.P.)	25	49	57	71	–
*Ratio	4.8	4.2	3.8	3.4	3.4										
Bajra	27.06	30.43	33.35	33.01	32.11	51.75 (Delhi)	67.00 (Haryana)	60.64 (Punjab)	56.25 (Maharashtra)	67.10 (Gujarat)	19	28	37	42	38
*Ratio	8.5	8.3	8.2	10.4	7.3										
Maize	39.76	43.76	42.36	43.38	42.40	61.92 (U.P.)	74.00 (U.P.)	83.75 (Mysore)	97.50 (Punjab)	82.20 (M.P.)	46	58	58	58	53
*Ratio	4.0	4.5	3.8	4.5	4.4										
Jowar	31.76	27.15	35.53	46.59	35.50	65.61 (Andhra Pradesh)	55.00 (Andhra Pradesh)	85.16 (Mysore)	99.44 (Mysore)	95.00 (Mysore)	12	26	39	68	59
*Ratio	7.4	5.3	6.5	8.9	6.9										

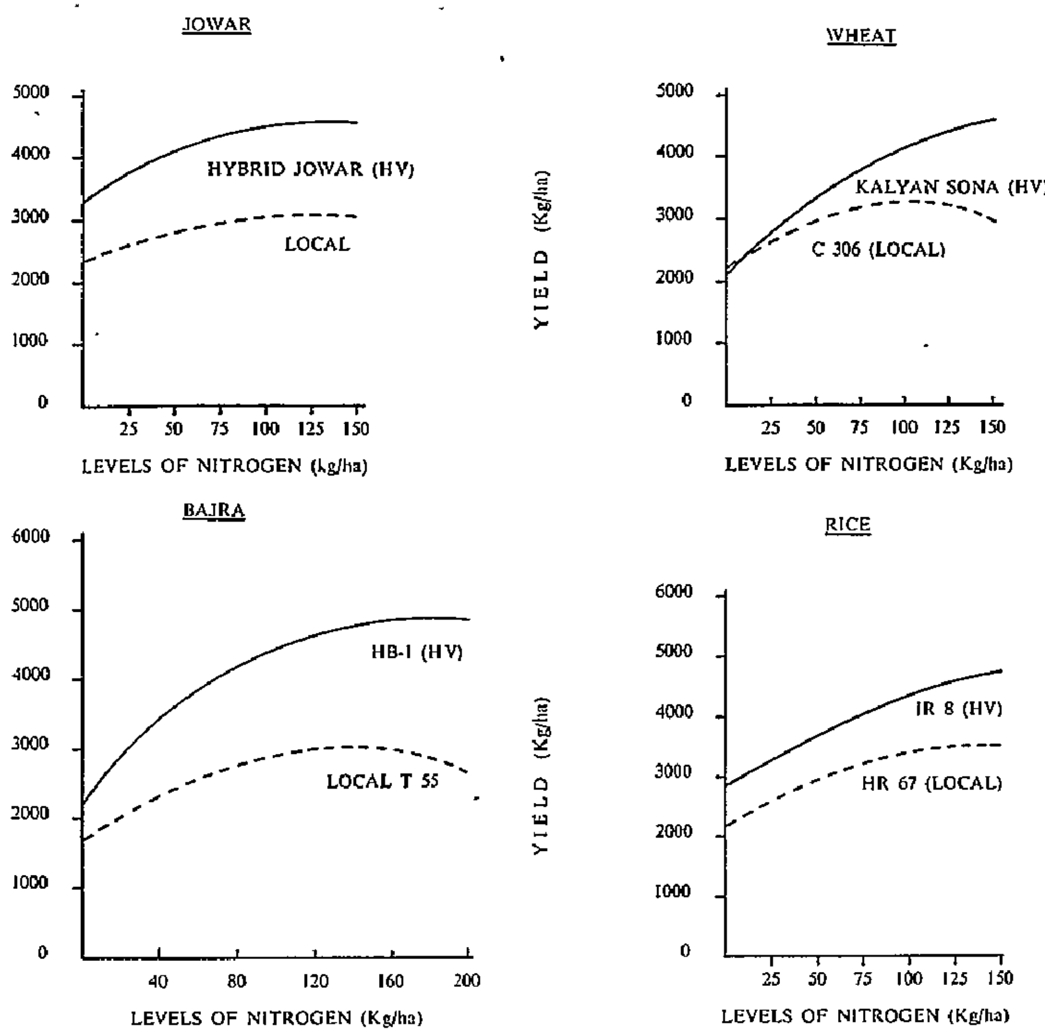
* Ratio between the average yield under National Demonstration and the average yield in the country.

SCHEMATIC DIAGRAM SHOWING THE EFFECT OF VARIOUS FACTORS IN CROP PRODUCTION

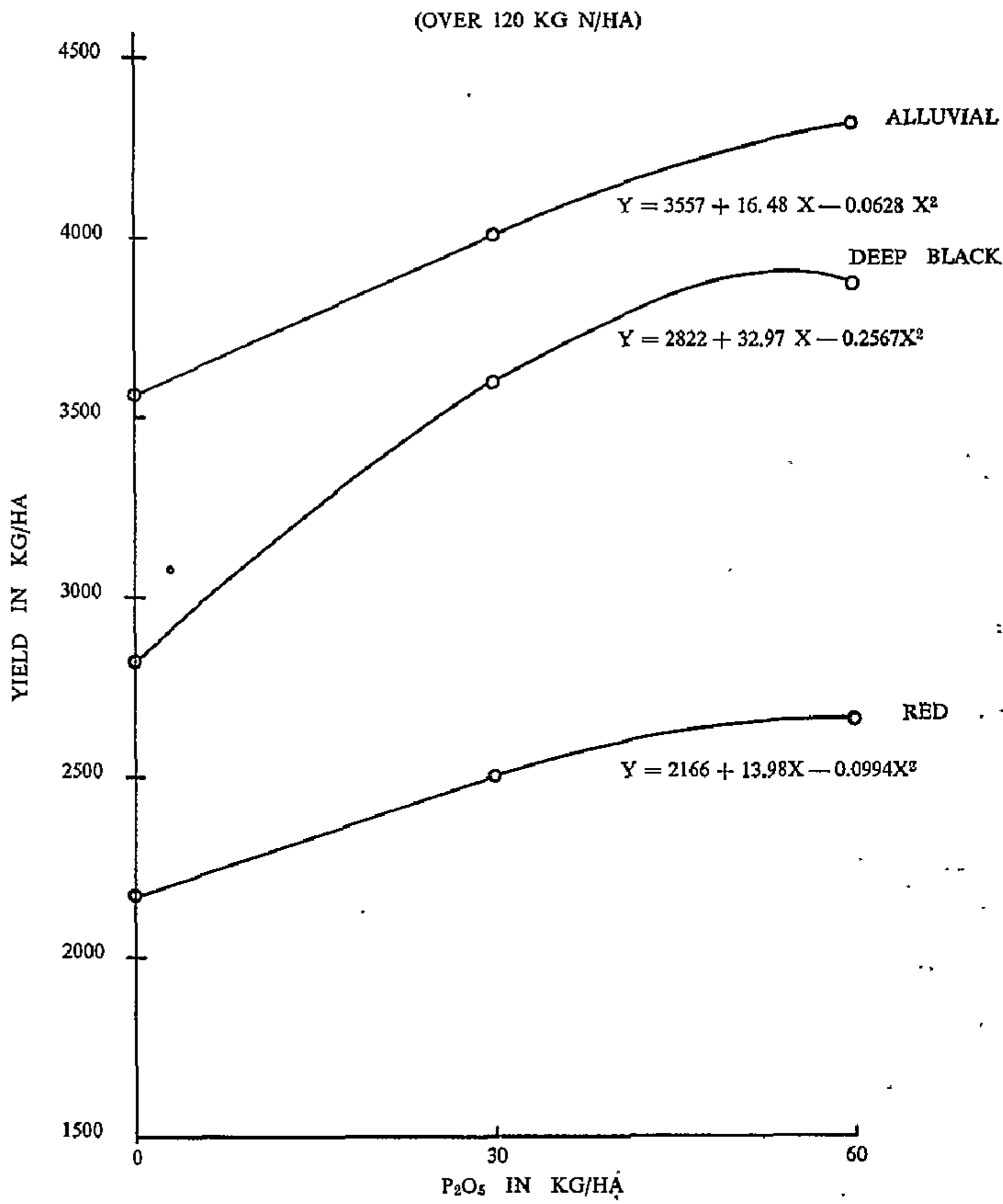


Source: From protective to productive irrigation by Dr J S Kanwar, Economic and Political Weekly, Review of Agri, March 29, 1969, Vol IV No 13 pp. 1–5.

EFFECT OF DIFFERENT DOSES OF NITROGEN ON THE YIELD OF LOCAL AND HIGH-YIELDING VARIETIES OF WHEAT, RICE, JOWAR (SORGHUM), AND BAJRA (PEARL MILLET)



RESPONSE OF WHEAT TO PHOSPHORUS ON CULTIVATORS' FIELDS



The All-India Coordinated Agronomic Experiments Scheme

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Agricultural research and development is a continuous process and coordinated research on a national scale has become very important in India's strategy for rapid agricultural development. This approach has proved to be extremely effective in (a) efficient utilisation of research resources for developing new technology and (b) testing, adapting and incorporating new technology in order to maintain a rapid growth rate in agricultural production. So effective has been the coordinated approach in a country like ours, with many different agro-climatic conditions, scattered expertise, difficulties in communications, variability in research organisations, etc. that the procedures are being studied and adapted by other countries.

The All-India coordinated research projects under the Indian Council of Agricultural Research (ICAR) have gradually developed into a three tier organisation. The first is the crop oriented schemes which are responsible for developing suitable varieties as well as the broad agronomic practices for individual crops. The second consists of adapting research results from the crop oriented schemes, as well as technology developed elsewhere, to the various soils and climatic conditions in the country. The third tier consists of 'national demonstrations' wherein the technology developed in the second tier scheme is demonstrated on the farmers' fields by qualified scientists.

The All-India Coordinated Agronomic Experiments Scheme (AICAES) comes into the second tier of the agricultural research organisation of the ICAR. It is an area-oriented scheme which carries out the important functions of adaptive research and rapid dissemination of the results of research and technology to all parts of the country.

HISTORICAL

The All-India Coordinated Agronomic Experiments Scheme is not only the largest and most comprehensive coordinated scheme in the country but it is also the oldest, initiated before the large scale introduction and adoption of modern agricultural technology.

The project was initiated on the basis of the report by Dr. A. B. Stewart of the MaCaulay Institute of Soil Research, Aberdeen, Scotland who was invited

in 1945 by the then Imperial Council of Agricultural Research to advise it in planning research in soil fertility. Dr. Stewart, in his evaluation of soil fertility work in India, pointed out the extreme paucity of information on this subject and recommended a stepped up programme of (1) thorough agronomic experimentation under rigid conditions at research centres to develop fertiliser recommendations and other agronomic practices for efficient crop production and (2) a programme of trials on cultivators' fields to obtain data on the fertility status of Indian soils, and to determine broadly the crop responses to nitrogen, phosphorus and potassium that could be expected under conditions on cultivators' fields. On the basis of his report a "Soil Fertility and Fertiliser Use Project" was initiated in 1953 with support from the Technical Cooperation Mission of the U.S.A. and this continued until 1956 when it was changed to the present form of the All-India Coordinated Agronomic Experiments Scheme. The project has continued through the second and third Five Year Plans of the Government of India with slightly different names but the organisation remained almost the same. At the beginning of the fourth Five Year Plan the project was provided with a full time Project Coordinator and a staff at the headquarters.

ORGANISATION

The All-India Coordinated Agronomic Experiments Scheme consists at present of the following:

(a) Complex experiments at 44 research centres (popularly known as Model Agronomic Centres).

(b) Trials on cultivators' fields in 30 selected districts with high yielding varieties of cereals.

(c) Trials on cultivators' fields in 20 selected districts under dry farming conditions with an annual rainfall of less than 750 mm per year.

The locations of research centres are changed only after a period of ten years or more while the districts under trials on cultivators' fields are changed every fourth year. The locations of the centres as well as the choice of the districts have been chosen to include all the major soil groups in the country. They also cover the major agro-climatic zones of the country.

OBJECTIVES

The main objectives of the experiments at research centres and trials on cultivators' fields are given below:

Experiments at Research Centres:

(a) To assess the production potential per unit area per unit time for different agro-climatic conditions of the country by adopting suitable multiple cropping systems.

(b) To obtain information on the response of high yielding varieties of cereals to different agronomic factors such as fertiliser (including micro-nutrients), irrigation, sowing dates, planting density, fertilisation, weed control, liming, etc.

(c) To evaluate various sources of nitrogen and phosphorus for different crops and areas.

(d) To study the manurial requirements of important crop rotations and their effect on soil fertility.

(e) To determine the most suitable cropping patterns and fertiliser responses under rainfed conditions.

Trials on Cultivators' Fields (HYVP and Dry farming):

(a) To study the response of high-yielding, improved crop varieties to nitrogen, phosphate and potash, singly and in combinations, under irrigated and dry land conditions.

(b) To compare different methods of application of nitrogen on cereals under dry farming conditions.

(c) To study the contribution of packages of soil and moisture conservation practices in combination with fertiliser practices to increase crop production in dry farming areas.

(d) To study the relationships between crop responses to fertilisers and soil test values.

(e) To formulate fertiliser recommendations for different soils and agro-climatic regions of the country.

The broad objective is to evolve suitable packages of practices for different cropping systems in various agro-climatic zones of the country.

PERSONNEL

Project Headquarters

The project headquarters consists of three components, agronomy, soil science and statistics, headed by a Project Coordinator under the overall supervision of the Deputy Director General of ICAR. The agronomy unit consists of an agronomist, one junior agronomist and two senior research assistants. The soil science unit consists of a senior soil scientist, one junior soil chemist and two senior research assistants. The statistical unit consists of a senior statistician. He is assisted by two junior statisticians and other supporting staff. The work of the project headquarters includes planning, guiding and coordinating research at the national level. It also undertakes statistical analysis of data obtained from the project, for interpretation of results and developing suitable recommendations on packages of practices for crop production in different areas of the country.

State/University Headquarters

The headquarters staff of each state consists of a full time scientist (officer in charge of the project), a chemist and a statistician. In states where there are agricultural universities, the project has its state headquarters in the university. However, in states where there is no state agricultural university, the state headquarters staff is provided by the state department of agriculture. The function of the state headquarters is to carry out soil and plant analysis of the experiments conducted at research centres and on the cultivators' fields, and statistical analysis of the data from the project for proper interpretation and recommendations.

Model Agronomic Centres

At each of the model agronomic centres one assistant agronomist/chemist and three field assistants are provided. Field experiments involving studies on soil

fertility and fertiliser use, irrigation and water management, cultural practices, weed control and multiple cropping are conducted in two seasons, *kharif* and *rabi*, at each model agronomic centre on crops important for the region.

Simple Fertiliser Trial Districts

In the districts under the programme of trials on cultivators' fields, one assistant agronomist is provided. In those districts where the high yielding varieties programme is in operation, eight field assistants are provided in each district while in the dry-farming districts six field assistants are provided. The assistant agronomists are provided with a vehicle and a driver in order to supervise the trials on the cultivators' fields efficiently. In each of the high yielding variety districts, 256 non-replicated 'ten-plot' trials are planned to be conducted per year. In the dry farming districts, 120 non-replicated trials are conducted each year.

OPERATION

The project staff meets annually at a workshop to review results and to plan the next year's programme. The technical programme and the annual reports are prepared under the guidance of the Deputy Director General, ICAR. After the programme is planned, the directives for its execution are issued from the project headquarters. The programme of work is also scrutinised from time to time by a committee headed by the Deputy Director General, ICAR. Beside the senior staff members of the project at headquarters, the other members of the committee are the Director, Institute of Agricultural Research Statistics, the Head of the Division of Agronomy of the Indian Agricultural Research Institute and the Head of the Division of Soil Science and Agricultural Chemistry of the Indian Agricultural Research Institute.

Two national level training programmes are organised each year before the cropping season to acquaint the scientists with the latest crop production technology. In the training sessions, the detailed technical programmes, as finalised in the workshop, are discussed. Similar training programmes are also organised in each state for the field workers.

After the experimental programme is communicated from the project headquarters to the state, the project headquarters' staff visit the operational units continuously to help implement the technical programme and provide general supervision. The results obtained during the year are presented in the annual progress report. Recommendations based on the results are passed on to the ICAR for use by the extension agencies responsible for agricultural development programmes in the country.

ACKNOWLEDGEMENTS

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Part V

Research on Economic and Social Problems

Socio-Economic Factors in Agricultural Development

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Concern was expressed as recently as 1967 that the race between population growth and food supply was being lost (The White House, 1967). Developments since then indicate that many countries are gaining ground toward self-sufficiency in food production and that others will attain this position before long (UN, 1969). This dramatic change in the Asian agricultural scene is attributed to the technological breakthrough referred to as the 'Green Revolution' or the 'Seed — Fertiliser Revolution'. This development may be interpreted by some as a breathing space in which advances in the field of population control would help bring about some equilibrium between population growth and food supply. To others, the green revolution is not based on a single set of innovations that would raise production to a new plateau only to level off again. Rather, it is viewed as a process that will provide an accelerated rate of increase in agricultural production into the indefinite future (Mellor, 1969). Similar hopes have been expressed in the past. But looking back on the period since the close of World War II and with the benefit of hindsight, one can point to many developments which did not live up to the early promises. As we move into the 70's the magnitude and urgency of these problems will increase and it is even more necessary that progress should not be slowed down because of a lack of knowledge of the production problems of small farmers or an improper understanding of the factors that hinder the modernisation process.

The problems and processes of agricultural development and the techniques and experience of countries at various stages of development have all been dealt with at length by a voluminous and growing literature. However, while a great deal is known of the various factors affecting growth and development, there is a dearth of information which would help pin-point the particular factors or combination of factors that should be stressed in a given situation and under a particular set of circumstances. A wide variety of programmes have been initiated over the years with the intention of improving the condition of the farmers. But success stories seem confined principally to pilot projects. Our main concern should therefore be to identify and explain the factors which seem to prevent farmers from responding favourably to such programmes.

This paper attempts to review some of the factors considered critical to the growth and development of agriculture in the context of current developments; it relies heavily on Ceylon's own experience with agricultural development pro-

grammes. While the problems of development are common to most of the countries in the region, we must recognise the 'micro-heterogeneity' of agriculture and avoid generalisations which may lead to inaccurate and harmful conclusions. This is especially important because our primary concern is with the problems that confront farmers as individuals in bettering their conditions.

DEVELOPMENT STRATEGY

The critical role of agriculture in the growth and development of the low income countries is widely recognised (Johnston, 1961). Agriculture is an industry of major proportions in many of these countries, providing employment for the bulk of the population, contributing to a major share of the national income and accounting for a substantial proportion of the foreign exchange earnings. What is done or left undone about agriculture will critically affect the ability to provide for the rapidly increasing populations of these countries and to contribute to the development of the other sectors of the economy.

Development strategy in these countries would, however, seem to give agriculture a rather limited role. Most countries in the region depend on agriculture to sustain a rising inflow of essential imports for their programmes of industrialisation. Simultaneously, a sizeable proportion of their imports consists of agricultural commodities, much of which could be produced domestically. The primary purpose of agricultural development would thus be the earning and saving of foreign exchange and emphasis is, therefore, given to the achievement of the fastest rate of growth of agricultural production (Ojala, 1969).

It is becoming increasingly evident that development plans must also have several other objectives in view. In the words of Dudley Seers, 'A plan which conveys no targets for reducing poverty, unemployment and inequality can hardly be considered a development plan' (Seers, 1969). Similarly, the Report by the United Nations Committee on the Second Development Decade headed by Jan Tinbergen concludes that while the First Development Decade of the 1960's focused upon production per se, the Decade of the 1970's must focus upon the abolition of poverty. Thus, agricultural development programmes must also have amongst their objectives the achievement of employment, improvements in income distribution and minimum levels of nutrition. The factors relevant to agricultural development must therefore be considered in their broader context.

FACTORS IN AGRICULTURAL DEVELOPMENT

Agricultural development has been a matter of concern for many centuries. One has little knowledge of some of the ancient civilisations which were characterised by the development of vast and intricate systems of tanks and canals; the present day ruins bear testimony not only to the skill of the people, but also to the predominant position that agriculture, especially rice production, occupied. Much of today's agricultural development in Ceylon lies in restoring these tanks and canals and building up new settlements (Farmer, 1967). One should draw attention, in spite of constant references to stagnant agriculture in peasant societies, to periods of rapid growth in agriculture in recent times. The development of export agriculture in Ceylon has been associated with very rapid rates of growth (Jogaratnam, 1964). It is unfortunate that very little work has been done to assess and draw on these experiences. Considerable attention, on the other hand, has been devoted to the historical experiences of countries such as Japan and Taiwan and these are

often cited as examples which the low income countries could usefully follow in their quest for modernisation.

The more recent history of agricultural development in some of the low income countries provides a good insight into the factors considered relevant at various times. If one takes Ceylon as an example, development strategy in the early years of this century was concerned with the provision of cheap and easy credit which was considered to be the critical factor limiting sustained increases in agricultural production. Thus, agricultural policy was mainly concerned with the sponsorship of rural cooperative credit societies. Ceylon, in fact, based itself on the Indian model which was influenced heavily by the Raiffeisen system. Cooperative credit did not prove to be the answer and interest shifted to irrigation, land development and settlement in the 1930s. The idea was that farm units were far too small to be economically viable and that new land had to be opened up under state sponsorship to relieve land hunger. With the war and the attendant food shortages, land settlement was considered too costly and too slow a process and interest shifted to marketing and land reform. Credit was then tied up with production and marketing and we had the beginnings of the multipurpose cooperative societies on which so much emphasis is being placed now. Ceylon also felt the impact of the post-independent sweep of land reform measures and legislation was enacted to regulate tenancy. Land reform did not, however, go so far as to involve redistribution of land and the fixation of ceilings on size of holdings.

These programmes have been accompanied by a scheme of incentive prices which guarantee the farmer a price for rice (which has continued to be well above world prices), input subsidies (particularly for fertilisers and seed paddy) and a crop insurance scheme (which covers only about 20% of the area under rice). Research and extension has not been neglected, either. A local hybrid variety, H4, with a production potential of over 160 bushels per acre was developed and released to the farmers as early as 1958. The importance of extension activity has also been long recognised, though the quality and coverage leave much to be desired.

The various measures undertaken by the government have had a certain effect. Rice production is estimated to have increased at an average annual rate of over 4.5% in the post-war period. In considering this development it should be pointed out that the major emphasis in the pre-war period was on the development of the plantation sector, although the resultant technological breakthroughs have received hardly any attention. The concentration of effort on rice production is a post-Korean war development and a period of 15-20 years is insufficient to expect any dramatic changes in a peasant economy. However, the pressures exerted by a rapidly increasing population and a worsening balance of payments position have resulted in an overall feeling of disappointment and pessimism at the considered slow rate of progress in food production. In retrospect, it is apparent that the fault lies in the implementation of the multitude of programmes designed to change peasant production. This problem will be referred to subsequently in more specific terms. In general, it can be said that implementation at the village level of policies conceived in aggregative terms at the national level requires a high degree of coordination amongst various arms of the government. This coordination seems most difficult to achieve. The administrative problems involved in implementing development programmes seem to be one aspect of development that has not received adequate attention in development literature.

Apart from the problems of implementation there are several other factors which could explain the lack of success of many of the development programmes.

Many of these measures were conceived on an ad hoc basis, in response to the pressures arising at different times. Very often, the emphasis was on single programmes which were the trend at the time, despite the existence of an array of programmes in the statute books. The sequence and timing of these programmes very often had little impact on the farmers, the supply of cheap and easy credit without adequate marketing facilities had little impact on production and guaranteed prices were ineffective when there was an absence of adequate storage and transport facilities. However, progress was made in spite of the existence of these and many other problems. Ceylon may perhaps be an exception in the wide array of programmes undertaken, but most other countries could similarly point to the increasingly active role of governments in agriculture and the steady progress in production.

Current development strategy with its emphasis on an integrated approach to agricultural development seems a logical development based on past experiences. A large number of factors are identified as being necessary for development. As Dr. Mosher summarises, the five essentials are markets, technology, local availability of input supplies, production incentives and transportation; the five accelerators are education, production credit, group action by farmers, land improvement and development, and national planning (17). Given the structure of peasant agriculture, it is argued that the impact of change must not only encompass all these factors, but must also be massive enough to bring about the required changes. Since limited resources prevent massive operation on a broad front, the need for some sort of selectivity in the use of resources arises; areas of high potentiality and low risks were chosen for a concentration of effort.

Today, the strategy of intensive agricultural development in selected areas constitutes an important aspect of agricultural planning in many low income countries. Questions have been raised whether governments possess the capacity and capability to cope with the multiplicity of limiting factors even in restricted areas of high productivity. It is argued that the principle of selectivity should be extended to determine priorities and sequence in which the various problems should be tackled. There is some evidence that the results may be greater if the major constraints can be identified and dealt with, as in the case of water in West Pakistan (Falcon, 1968). However, the technological breakthrough referred to as the 'Green Revolution' has given added force to the strategy of concentrated effort in selected areas and the problem must be considered as a whole in the context of the new developments. The development of the new high yielding varieties of grains and their rapid adoption in selected areas of West Pakistan and Indian Punjab and Tanjore with remarkable results has aroused a great deal of enthusiasm. The FAO Indicative World Plan projected that by 1985 India and Pakistan would be in a position to export grains or feed them to livestock (U.N. 1969). The 'Green Revolution' reflects the potentials for development. The basic concern is whether the potentials can be realised and how soon, and to what extent it would help in the eradication of poverty, unemployment and malnutrition.

RESTRAINTS IN EXPLOITATION OF NEW TECHNOLOGY

The 'Green Revolution' has as its basis the development of high yielding varieties. There is evidence that the spread of these varieties has been much more rapid than generally anticipated. However, it is by no means certain that this will continue, leading to a sufficiently wide adoption of the new varieties. The manifold factors that influence the rate of adoption have received considerable attention and have been well documented (Barker, 1969; FAO, 1968; Johnson and Couston, 1970; Mellor, 1969; Mellor, 1969; Mosher, 1969; Wharton, 1969). In areas where the

rate of adoption has been rapid, it has led to what are referred to as second-generation problems. These relate mainly to problems of marketing and storage. Production increases could be so overwhelming that the existing marketing framework may not be able to cope with it. There is also the possibility that the existing institutional framework may not permit an adequate supply of the increased inputs such as fertilisers and insecticides. Where the farmers have realised the economic advantages associated with changes, the attendant problems should not be too difficult to overcome. The broad framework of policy exists and the authorities should be able to cope with any bottlenecks.

There are likely to be other more difficult problems. These may possibly influence the margin of economic advantage beneficial to individual farmers and would be of critical importance in determining the rate of adoption of the new technology. Here again, there already exist policies at the national level relating to prices and support programmes, credit arrangements, input subsidies, marketing, etc. These are all part and parcel of the 'package programme' or 'Intensive Agricultural Development programme' which have been accepted by most countries as the major strategy in agricultural development planning. The problems arise in the actual implementation of these programmes and assume more serious proportions because the new varieties are very specific in their requirements of water, fertilisers and other inputs, and management practices.

The spread of the new varieties is directly related to the extension of the area under assured water supplies. In some areas, as in West Pakistan and the Indian Punjab, the yield advantage and physical conditions make private investment on tube wells profitable. In other areas, the water supply is dependent on the construction of costly dams with long gestation periods. It is noteworthy that the irrigable area is estimated at approximately 20% of the total arable area for ECAFE countries as a whole. In Ceylon irrigable extent does not necessarily mean an assured water supply. Thus while it was once suggested that agricultural development strategy should make minimum demands on capital, it now appears that investment requirements for rice growing at least will be very high (Hsieh and Ruttan, 1967). Water control is more important than water availability and individual farmers face many problems on this. Large irrigation systems in Ceylon are based on gravity flow and the rate and timing of water release is beyond the control of individual farmers. The spread of new varieties and new practices such as multiple cropping and crop diversification is apt to be slowed down in the absence of adequate individual water supply control. It is doubtful whether existing irrigation systems can be redesigned except at enormous cost.

Attention has been drawn to problems such as the increased susceptibility to diseases and acceptability of grain quality, all of which it is felt could be overcome in a comparatively short time (Barker, 1969). It is important to note that many of these problems vary from area to area and require decentralised action. The need for a considerable amount of adaptive research has been stressed. This would depend on the speed of availability of trained personnel, buildings and equipment.

A major problem is the higher levels of investment and risk attached to the adoption of the new varieties. Since the new varieties are highly specific in their requirements and demand a much higher level of managerial competence, yield potentials are not always realised. This means that the yield advantage over local varieties is not always great enough to induce farmers to adopt the new varieties. Even those farmers who are conscious of the advantage insure themselves by re-

stricting the new varieties to a portion of their holdings. It is, therefore, difficult to find an area where an entire holding is planted with one variety. This would seem to support the view that farmers, in order to reduce risks, do not obtain the maximum profit (Lipton, 1968).

The problem is more acute where the small farmer who dominates the peasant economy is concerned. For example, in Ceylon nearly 60% of all agricultural holdings is under two acres. Most operate under rainfed conditions but evidence indicates that their yield per acre is higher than average. It is unlikely that they can be induced to plant the new varieties and the success of the 'Green Revolution' without price guarantees and input subsidies will weaken their position. It is inevitable that there would be a growing disparity in income, but there does not appear to be any policy to minimise the problem. One solution would be to encourage these farmers to plant new crops. This is likely to be a slow process, as one has to begin to do research on new crops, alter price structures and persuade farmers to give up rice production. In countries like Ceylon where agriculture is already heavily subsidised, such changes would only increase the burden to the government. Experience indicates that guaranteed prices can seldom be lowered and upward revisions of prices of commodities other than rice will increase the burden to the government.

Mass unemployment which may occur in the 70's is associated with the problem of low incomes. In view of the importance of agriculture, development methods which increase employment opportunities inside and outside its limits, therefore need critical examination. It is conceded that the absolute size of the population in agriculture will continue to increase for several decades and a solution to the employment problem cannot be found solely by creating alternative employment opportunities outside of agriculture (Ahmad and Sternberg, 1969). The agricultural sector must offer employment to increasing numbers of people and this may prove difficult in countries with limited land resources.

It has been argued that the resources such as land, water and capital which complement labour are under-utilised in many of the low income countries and that the obstacles to improved utilisation can be attributed to the structure of agriculture itself (Ahmad and Sternberg, 1969). Thus, attention has been drawn to the heavy concentration of land ownership and a case made for widening land ownership. However, redistribution of land in itself cannot provide a solution to the problem of unemployment. It has to be associated with several other measures which would increase production (Warriner, 1969).

Apart from altering the structure of agriculture, the potential of the 'Green Revolution' to absorb additional labour is tremendous. There is evidence to show that the high yielding varieties of seeds require relatively more labour. New technology leads to multiple cropping and crop diversification with labour-intensive high value crops; this, in turn, will need much higher labour requirements on farms. We should, however, not ignore the possibilities of a better utilisation of family labour as opposed to an allround increase in employment opportunities within agriculture. The year-round cultivation and more scientific rotations may reduce the seasonal peaks in labour requirements and lessen the opportunities for hired labour. This is, however, an area where more information is needed than is available at present.

The widespread tendency to mechanise agricultural operations in some of the areas which have felt the full impact of the 'Green Revolution', as in West Pakistan, has been noted (Cownie, Johnston and Duff, 1970). The need to en-

courage selective mechanisation and to adopt positive measures to prevent labour displacement has been suggested. Recent studies indicate a similar tendency in rice production in Ceylon. The problem is, however, complicated by labour shortages in settlement areas and difficulties in inducing labour to migrate (even seasonally) from surplus areas, the importance of timeliness in operations, a shortage of buffaloes as well as other factors.

In considering employment problems in agriculture, one should also refer to the new class of educated unemployed who find agriculture unattractive. This type of unemployment is becoming an increasing problem in Ceylon where there has been a scheme of free education at all levels for over twenty years. Employment in agriculture is considered unskilled labour and there is a preference for white collar jobs. The blame lies in the educational system and the solution may be increased opportunities for technical and agricultural training. This, however, does not solve the immediate problem of finding employment for thousands or potentially millions. A recent attempt to provide educated youths with employment opportunities in agriculture in Ceylon is very illustrative: The government announced a pilot scheme to provide selected youths with two-wheeled tractors for hiring service; however, very few youths accepted the offer in spite of the serious unemployment situation. The fear of a lost opportunity for a white collar job may be the reason for the failure of the scheme. The problem is that an average sized holding of 1—2 acres does not give an adequate assurance of making a living out of agriculture. There are many examples of intensively farmed small holdings which sustain a relatively high standard of living, but with the present information and the limited financial, technical and administrative resources available, it is difficult to repeat them on a large scale.

One should also consider whether the success of the 'Green Revolution' in selected areas would generate employment outside agriculture. One would expect an increased demand for durable consumer goods. The impact does not appear to be as great as that expected, probably because of the high marginal inclination to consume and a high income elasticity of demand for food. A fast agricultural development has also not given any evidence of supporting an increased rural public works programme. The administrative problems involved in bringing farmers into the tax structure as well as the political unpopularity of such measures has prevented any channelling of the gains in income for such purposes. Evidence available also does not indicate any appreciable increases in rural savings. These are, however, areas in which very little information is available and there is need for investigations which would help explain the lag, or in some cases the absence, of spread effects.

SUMMARY

To summarise the discussion presented so far, it would appear, at least as far as Ceylon is concerned, that there exists a broad framework of policy which recognises the need to help the peasant farmer tide over a wide array of problems. Appropriate policies exist in respect of land tenure, credit, marketing and prices, with the state also endeavouring to ensure adequate supplies of fertiliser, improved seeds and other inputs. These basic policies have their shortcomings — land reform measures ignore the problem of fragmentation and parcelisation and agricultural credit concentrates solely on production despite evidence of production credit being channelled for consumption purposes. These shortcomings are due more to inadequate administrative and financial resources than to lack of understanding. Although all these measures have had an impact on production, it is apparent that

farmers have not derived the full benefits. Those who have observed the process personally and at the farm level have noted that the implementation of these programmes must be improved.

With the advancement of technological breakthroughs the implementation of development programmes assumes critical importance. The new varieties are highly specific in their requirements of water, fertiliser, management practices etc., and if there is to be a sufficiently wide dissemination of the new varieties, it is necessary that the obstacles at the farm level be removed. This would require a greater knowledge of what these problems are as well as an administrative framework that would bring about a high degree of coordination amongst the several agencies that now seek to help the farmers.

It is also being increasingly realised that the new technology will increase the disparity in incomes between farmers and between regions. This seems to be an inevitable part of the strategy of intensive agricultural development now being pursued. As a result of the attention placed on production problems, not much concern is being given to the problems of those farmers who are being bypassed by the 'Green Revolution'. This will increase the social tensions which are beginning to become apparent.

The problems of the small farmers farming 1-2 acres require considerably more attention. These farmers form a big majority in most areas. It appears that the new technology will barely affect their social and economic viability. We need to know much more about them, the reasons for their lagging development and to find a solution for them. We will have to develop new crops, new systems of farming and new combinations of enterprises to help these farmers. We will have to discover whether these will provide a solution or whether the answer is something apart from agriculture.

Finally, the employment potential of the new technology needs careful investigation. It is certain that for a long time to come, agriculture will have to remain the major source of employment. A great deal of research is indicated if agricultural development is to be designed to absorb the maximum numbers of workers possible. There also seems to be an inadequate understanding of the process by which developed areas can induce development not only in the backward areas but in the rest of the economy as well. The backward and forward linkages and the spread effects do not seem to work quite as smoothly as postulated in theory.

It would thus appear that all the factors mentioned above indicate the need for a fresh approach to planning. In recent years, the necessity for 'planning from below' has attracted considerable attention. It appears, however, that we know far less of the techniques and methods of planning from below than that of planning from the top. This may be explained partly by the aggregative approach of most plans and partly by the 'urban bias' of most of the planners themselves (Lipton, 1968). Whatever the reason, it must be realised that the rate of agricultural progress in the next decade will depend largely on the mobilisation of active farmer participation in running development programmes in a farmer-government partnership.

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Priorities for Research in Agricultural Economics

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In this paper I propose to suggest some priorities for research in agricultural economics in the developing countries.

The availability of the new high-yield technology and a larger quantum of national and international resources for agricultural development has made it urgently necessary that some priorities be established. For in the absence of relevant empirical knowledge resources can be grossly misallocated. A wrong allocation can produce very undesirable consequences in respect of the relative growth of the output of different crops, their prices, farm income and employment. In so far as these consequences can be observed and foreseen policy makers can take corrective measures.

To the technologist research which increases physical productivity is an absolute good. But from the economic point of view it is good only so long as it increases net farm income without grossly unpleasant side effects. Therefore economic research must accompany all the processes of technological change and provide a continuous feedback to the policymaker for course correction, whenever and wherever this change is producing or is likely to produce unwanted consequences.

INPUT-OUTPUT COEFFICIENTS

The collection of farm data about input-output relations which has been traditionally a major activity of agricultural economists, particularly farm management specialists and production economists, must continue on an expanded scale. But in the changed context a change in the focus of data collection is necessary. When the production function has begun to shift continuously as a result of technical change, farm studies should be designed to measure this shift at discrete intervals rather than record a set of static relationships. The survey samples have to be stratified (a) by crop-pattern zones, (b) by water availability, (c) by level of technology and (d) by degree of mechanisation. Researchers and policymakers should get a continuous flow of data on input-output ratios at different points of time in each sub-sector of agriculture defined by the above criteria.

This information is crucial for gauging and comparing the realised rate of technical change in different regions and sub-sectors, and for projecting the output of each crop on the basis of input availability.

RETURN-COST RATIOS

Data on physical input-output relationships should be distinguished from data on financial return-cost relationships, though the latter are obviously based on the former. Both can be collected together in the same surveys. While physical input-output relationships measure production possibilities, return-cost relationships reveal the cost and income potentials of every technique in a given price milieu. The effect of technical change on farm incomes, and the rate of technical change itself, depend not on the physical efficiency of inputs but on the return-cost ratios. Therefore, the dynamics of these ratios should be charted for each technique, region and sub-sector.

This information is necessary for the policymaker to regulate the growth and distribution of inputs, to project income growth, and to adjust input and output prices.

DEMAND AND OUTLOOK STUDIES

These studies of the supply side of growth have to be supplemented by studies attempting aggregative demand and price projections. The crucial importance of these projections is that they can indicate emerging shortages and surpluses, price increases and decreases. With these forecasts the policymakers can, again, regulate the growth of inputs and adjust prices so as to minimise the probable income losses of consumers and producers.

In short, as technical change accelerates, agricultural economic research must give the highest priority to the measurement of technological change itself, and the projection of supply, demand, income and prices for each region and sub-sector of agriculture.

Side-studies of the growth of individual inputs, of the administrative and institutional structures affecting the distribution of inputs, the rate of diffusion of innovations etc. should be directed toward the central purpose, namely, the projection of these magnitudes and the continuous adjustments of policy in the light of these projections.

PROJECT EVALUATION/BENEFIT-COST ANALYSIS

In most poor countries technical change in agriculture requires massive investments by governments in the creation of the needed infrastructure for rapid growth and in the direct production and supply of critical inputs. These investments are embodied in projects — irrigation and power projects, fertiliser projects, road construction projects, warehousing projects, pesticide production and supply projects, agricultural equipment production and supply projects and rural credit projects. When the available capital resources are extremely limited in relation to the requirements of these projects, it becomes urgently necessary to select for each period only those projects which promise the highest net social return.

Traditionally, agricultural economists are not supposed to acquire any proficiency in the techno-economic evaluation of large public-sector projects. But I suggest that in the present changed situation, with increasing infusions of technology in development, the acquisition of such proficiency must be made compulsory for all agricultural economists.

The growth and distribution of farm income depends so critically on the characteristics and location of projects selected by governments for implementation in each period that the highest technical competence should go into their selection. A large body of published literature has been developed in recent years in this area, and a large amount of unpublished case material is also available in the archives of the big national and international financing agencies. All that is needed is a programme of workshops to train agricultural economists in the science and art of project evaluation with the help of these materials.

Project evaluation should also become a major field of research in agricultural economics. And administrators should be persuaded to associate economists trained in this field with investment decisions. Some lending agencies and administrative branches have begun to insist on proposed project reports giving all the data required for the calculation of various measures of social cost and return. But in most decision-making bodies the processing of projects still remains utterly ill-informed and irrational. As a result, enormous resources are being wasted on technically and economically unsound projects.

The evaluation of completed projects *ex post*, and the concurrent evaluation of ongoing projects, are as important as the evaluation of projects *ex ante*. For the knowledge required for *ex ante* evaluation can only emanate from *ex post* studies.

DISTRIBUTION AND UNEMPLOYMENT

Unlike the economies which are already developed, the economies which are now in the process of development have to attach as much weight to equity and employment as to the growth of output, because of the explosive political environment of contemporary growth. Therefore, the rate and kind of technological change in agriculture has to be regulated, to the extent possible, so as to minimise its adverse distributional and employment effects. Field studies are required to throw up the needed empirical evidence on what these effects are. Contradictory assertions continue to be made, for example, about the effects of tractorisation and the merits and demerits of skewing the distribution of inputs — seed, water, fertiliser, pesticides, equipment, electricity and credit — in favour of big farmers and of areas already well-endowed by nature in respect of weather and water supply and soil. What is clearly needed are authoritative field studies of the precise distributional and employment effects of each type of technical innovation in different regions and sub-sectors. For such studies, if they are to be deep and illuminating, villages are better units of study than samples of farms from large areas.

In the absence of solid empirical work, policy will continue to be guided by unverified assertions and political pressure.

AGRICULTURAL AND GENERAL GROWTH

Finally, it is necessary to urge the need for aggregative studies of the dynamic interaction of agricultural and non-agricultural growth in respect of the flow of labour, the flow of funds, and the flow of food, materials and manufactured goods. For the growth of the incomes of farmers and landless labourers depends as much on non-agricultural growth as on agricultural growth.

CONCLUSION

The above list of subjects on which research is urgently necessary is not exhaustive. But the main directions of advance have been indicated. Agricultural economists clearly have a heavy agenda before them and their work can be extremely useful and even indispensable for policy makers who have to promote and regulate the consequences of accelerated technical change. It is to be hoped that the needed wisdom and resources will be available for the purpose and that agricultural economists will have the professional competence to meet the challenge.

The Agri-Business Approach—The Philippine Experience

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I was asked to discuss "Using the Agri-business Approach — The Philippine Experience". In doing this, I will approach agriculture as a business system, showing in the process how we have progressed and what factors were responsible for this progress. I believe that, borrowing heavily from Drs. Milo Cox, Moseman and Mosher, it will be easier to explain this subject with the use of this chart. *(Appendix)*

THE AGRI-BUSINESS STRATEGY

In 1966 we were heavily importing rice. Demand was constant. Retail prices were relatively high because cost of production was high in view of low yields of traditional varieties. We did have IR-8 and other improved varieties which had just become available, companies engaged in the production of pesticides and insecticides, and fairly good credit facilities through two Government credit institutions — the Philippines National Bank and the Development Bank of the Philippines — and about 300 to 330 rural banks. We also had a fairly good irrigation system which, unfortunately, was largely in a state of disrepair. The missing input — the missing link — was a coordinated Government approach to putting these factors together. All the individual components for success were present, each one available for the farmer, but they were not offered in a concerted fashion. This was not conducive to a take-off.

As in a Symphony Orchestra, it is not enough simply to have all the instruments and musicians present. What is required is an effective conductor to produce harmonious and beautiful music This. was provided by Secretary Rafael Salas, our Vice-President, and President Fernando Marcos. The first step — the strategy adopted under the leadership of these able administrators — was to link up the extension services, which were under the Office of the President and divorced from any of the research organisations, with research and training institutions and also with credit institutions and all other Government agencies involved in one way or another in the rice production programme.

At peak, 21 different Government agencies were involved in the new Rice and Corn Production Coordination Council which we created in 1966. The Council

gave powers to the Chairman and to the 'Action Officers' to coordinate the contributions of the 21 agencies. The Council proceeded to draw up a master programme, based on a few high priority areas, chosen on the basis of the analysis mentioned by Dr. Mosher in his book *Getting Agriculture Moving*. In about 10 provinces, which had the greatest potentials in terms of immediate yield increases, the Council assigned roles to the 21 agencies and then supervised them closely for over two years. Incidentally, very little new funds were poured into this programme, reliance being given mainly to existing budgets of the respective agencies. The objective was to maximise the use of our inputs and resources.

Secondly, the Council proceeded to establish linkages with the private sector. We in the Philippines are essentially 'private-sector — oriented'. What we did was to make sure that the private sector knew which were the priority provinces, what kind of credit facilities would be available, and so forth. The entire effort was to ensure availability of inputs in the areas at the times needed. In fact, between 1966 and 1970, the private sector set up about 1,100 units of grain driers, 3 modern rice mills, 3,000 four-wheeled tractors, and 6,000 units of hand tractors. All the fertiliser requirements were produced domestically with the collaboration of ESSO.

The third thing the Council did was to remove the existing bottlenecks in the credit system. It is too laborious to go into the details but suffice it to say that we set up guaranteed loan funds borrowed from various credit institutions in order to make the loan system operative for farm machinery loans. In addition, we established a supervised credit system in rural areas. Also, the President consciously diverted funds away from industry uses and non-rice credit into the rice production programme by instructing the financial institutions to re-direct credit towards rice. As a result, programme loans grew from 9 million Pesos in 1966 to 577 million Pesos by about 1968.

The Government then proceeded to revive the guaranteed minimum (floor) price system, to stabilise the price at a level which would insure attractive returns to growers of the new high yielding varieties.

The Council, again under the instructions of the President, was given a big say in the direction of the massive public works programme that was started at about the same time. Essentially, money was channelled away from building main highways to the construction of feeder roads in order to provide farmers with better access to markets. About 1,500 kilometres of such feeder roads were built in about three years.

The Council then proceeded to train 5,000 technicians and production supervisers and about 22,500 farmers. At the same time the Council coordinated and helped step up the irrigation programme of the Government, concentrating not on long term construction of dams but on repairing of communal systems in priority areas. In two years, the area under irrigation increased by 200,000 hectares or by about 75 per cent. We also concentrated on ground water resources through pump irrigation and speeded up dam construction works already started to get these completed in a fairly short period of time.

MEASURES OF SUCCESS

The result of all this was a rice-production revolution that made us self-sufficient in rice in the brief period of two years. The original programme was aimed at self-sufficiency in four years — 1966 to 1969. What happened was that

by June 1968 self-sufficiency had been achieved, and in fact we re-exported some of the rice which we had earlier brought in as buffer stock. We also exported roughly 6,300 tons of certified seed of the improved varieties in 1968. Where, before, we were able to achieve only small increases in production, mainly by additional hectarage, we now had increased production by increases in yield. Our national average jumped from 30 cavans per hectare in 1966 up to 43 cavans in 1968. As a result of the additional increase in production in 1968 we stabilised rice prices, even in the traditionally lean months of the year which were hitherto characterised by sudden fluctuations in prices. The fluctuation in 1968 was 14 per cent instead of the 44 per cent in the previous year. We also ended up in 1968 with the largest government buffer stock ever in our history, with some 10.3 million cavans representing more than 10 per cent of actual consumption in that year.

It might be interesting to note also that the sales of all types of tractors had increased by 100 per cent in 1967. An equal increase was registered in the irrigation and pumpset sales. It was clear that the farmer was bent on increasing his production through mechanisation of his farm.

Finally — a most important point because of its deep social implication, and in support of Dr. Chandler's earlier statements — the rice revolution was spread out to cover not only the big farmer, the wealthy landowner, but also and especially the small farmers. This is shown by the spread of high-yielding varieties to over 33 per cent of our rice farmers. We expect, in fact, this season to have approximately 45 per cent of the total area in the high yielding varieties.

WHAT WE FAILED TO DO

These were the things we did, the strategy we adopted. What were the things we did not do? In the first place, in 1966 we decided to place priority on increased output and not so much on land tenure changes, on land reform. What else was not done? There was little attempt to reduce the spread between farm prices and cost to the consumer. We did not at that time, in 1966-1968, concentrate on improving the marketing system or market news services, nor did we do much on storage, processing or distribution. We overlooked, or in any case did not attempt to strengthen, the cooperative movement or the local organisation in the process of development, unlike the experience of Taiwan. We worked directly from the national government to farmers. I do not know if we would have done that in retrospect.

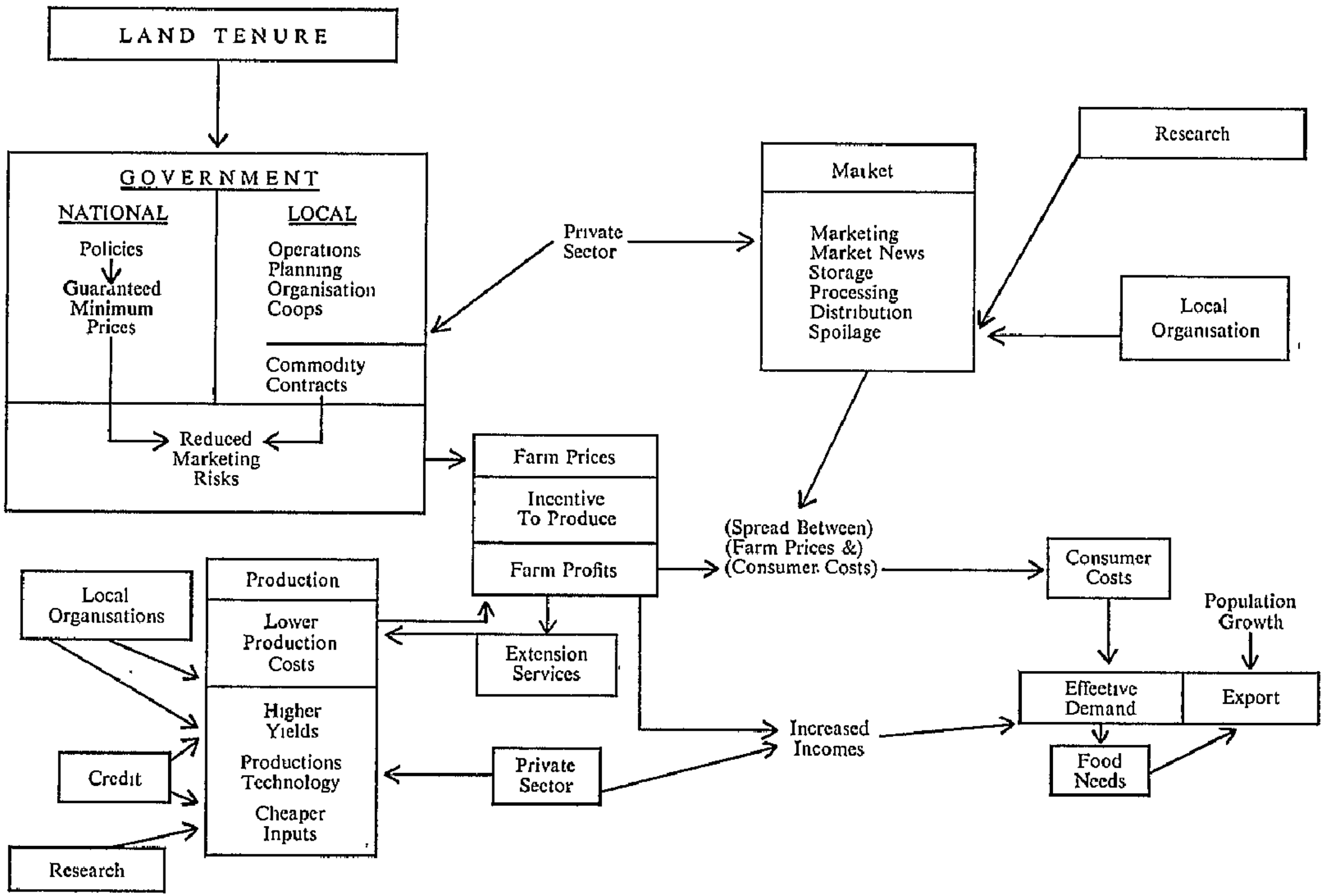
But success did come, and has persisted till now despite a severe drought in 1968 and 21 typhoons in 1970. We have maintained self-sufficiency. Prices of rice remained steady from 1966 to early 1970. The high-yielding varieties have continued to spread throughout this period. The continuous varietal improvement results of IRRI have been grabbed as they emerge and successfully transplanted into actual production.

Moreover, we have not found that labour has been displaced by farm mechanisation. We do have evidence that labour use has gone down to some extent for land preparation, but this has been much more than made up in weeding, harvesting and threshing operations.

ELEMENT OF INSTABILITY

Let us now come to The Philippines Case — Phase II or 'Success Revisited!' There are dangerous elements in the present situation. We assured the farmers a guaranteed price, but politicians wanted to protect the consumer's interests as well and set the ceiling price for selling rice at 30 per cent less than the cost at that time. By late 1969-70, therefore, the rice price stabilisation agency had been immobilised. The second factor which tended to disrupt the beautiful equilibrium of 1969 was devaluation in early 1970. In 1970 tight credit measures were enforced. This, in turn, reduced agricultural credit. Therefore, it tended to reduce the amounts of production inputs used by the farmer resulting in lower yields and lower farm income.

We require more research attention to factors of agricultural administration, to improve effective coordination and linkages of all factors that make up the agricultural business. We also need research on economic and social factors that have emerged from the agricultural revolution, for the use of policy makers and administrators. We need a lot of agricultural research on multiple-cropping, or mixed farming to diversify our agriculture. This will be the next development in the Philippines. The next phase is complex, it may appear to be somewhat 'confusion-confounded', but it looks hopeful.



LAND TENURE
GOVERNMENT
NATIONAL
Policies
Guaranteed Minimum Prices
LOCAL
Operations
Planning
Organisation
Coops
Commodity Contracts
Reduced Marketing Risks
Private Sector
Market
Marketing
Market News
Storage
Processing
Distribution
Spoilage
Research
Local Organisation
Farm Prices
Incentive To Produce
Farm Profits
(Spread Between)
(Farm Prices &)
(Consumer Costs)
Consumer Costs
Population Growth
Local Organisations
Production
Lower Production Costs
Higher Yields
Productions Technology
Cheaper Inputs
Extension Services
Credit
Research
Private Sector
Increased Incomes
Effective Demand
Export
Food Needs

APPENDIX

Part VI

Summary and Assessments of the Seminar

Discussions of Selected Issues

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A number of the more critical factors involved in the development and improvement of research institutions were discussed during the Seminar. Some of the points identified as especially significant are worthy of note.

RESEARCH MANPOWER

The shortage of research personnel at all levels — from qualified scientists through technicians and service or support staff — is a major deterrent to improvement of agricultural research capabilities in Asia. The following factors should be given attention in the recruitment, development and management of research personnel:

1. Position standards and requirements should be clearly defined to ensure selection on the basis of professional capabilities and to minimise pressures for appointment of unqualified personnel.
2. There must be substantial flexibility in staffing of research organisations, to avoid excessive rigidity in the number of posts and in the levels or grades of positions under circumstances where there are limited numbers of scientifically trained persons from which to choose.
3. Promotion procedures should provide for evaluation of performance and advancement on merit, embodying the concept of 'evaluating the man in the job'. The selection and promotion of research personnel must be based largely on judgments and recommendations of research scientists to insure maximum attention to professional values of research productivity, commitment and motivation.
4. Procedures should be established in the recruitment and promotion of scientific personnel to minimise excessive emphasis on seniority.
5. There should be more effective utilisation of scientifically qualified personnel, to avoid assignment of the already limited research manpower to non-research functions. This will require the establishment of a strong institutional base as well as effective procedures to facilitate recruitment, promotion and retention of research workers.
6. Salary levels are only one factor in attracting and retaining research personnel. Flexibility in furnishing equipment, supplies, and supporting staff is frequently an equally critical factor.

7. More attention should be given to the identification of those educational institutions in Asia particularly suited for training of research and supporting personnel.
8. Special attention should be given in the selection of persons for training in research to their depth of interest in and commitment to potential research careers.
9. Persons selected for specialised training programmes, such as those at IRRI and CIMMYT, must be properly qualified for the levels and types of training and experience provided at these centres.
10. There is need for training in research administration and management as well as in the various scientific disciplines.

It is recognised that the development of improved procedures for recruitment, training and management of research personnel should be designed to meet positively the needs of research organisations and not to promote considerations for research scientists as a special group.

FACILITIES

The inadequacy of research facilities, especially land areas of sufficient size and suitably located for field experiments, is a limitation to effective agricultural research in many countries of Asia of significance equal to the shortage of scientific manpower.

In building and maintaining the working facility base for a national research system the following points should be kept in mind:

1. The location of research stations and facilities should be determined primarily on the basis of technical factors such as soil types, representative climatic conditions, and the numbers and locations of stations actually needed in the system, rather than on political judgments or pressures emanating from desires to have 'research stations' set up in constituencies for prestige purposes.
2. It is essential that field stations, laboratories and other research resources be under the control of the research organisation, in order to avoid diversion of such facilities to other functions. The strong emphasis on programmes which have greater visibility than research in suggesting an action-oriented effort has resulted in the gradual disintegration and diminishing of experiment station resources in some countries in the region.
3. There must be continuity of field experiments on representative soils of known cropping history to build up reliable records of research results as the basis for recommendations to farmers. Migrating 'test-demonstrations' do not furnish results suitable for dependable interpretation and recommendations.
4. The quality or sophistication of facilities and equipment for agricultural research should be consistent with the scientific requirements in agriculture but yet in keeping with research facilities in other fields.
5. Appropriate attention must be given to experiment station development, operations and management. This was spelled out effectively in the paper by Dr. Harwood and his colleagues.
6. Research stations should avoid commercial operations. The production of basic seed stocks or planting materials is a function of a research institution, but the gathering of revenues from such operations should not become a dominating factor.

7. Close collaboration of research stations with practical farming and commercial scale operations is desirable to determine the economic feasibility of innovations and to guide recommendations.

FUNDING

Research programmes must be flexible — to respond to opportunities to utilise constantly emerging improved new techniques and knowledge or to proceed promptly to meet unexpected hazards from continually changing diseases, pests, or other limiting factors.

Most agricultural research requires continuity — for 3 years as a minimum for most projects, for 5 to 10 years for many others, and forever for some. The latter is true for research in crop and livestock protection.

The customary annual budgeting and piecemeal allotment of funds during the budget year is a major stifling restraint to planning and operation of research, particularly in countries where budget planning is geared to a 'cost and returns' basis and where fiscal efficiency is correlated with strict control of allocations.

An especially inhibiting factor — one that is counterproductive in the effective use of public funds — is the practice of apparent budgetary approval for a total research programme at the beginning of the fiscal year and the subsequent requirement for detailed justifications for release of funds to support various components of the total programme during the year. This not only prevents effective planning and restricts effective pursuit of research objectives but — most important — diverts time of research scientists to the task of writing detailed explanatory notes and 'justification statements' acceptable to treasury officers who are usually not trained or experienced in research.

A companion problem emerging from the lack of familiarity with research on the part of finance officers in government is the tendency for lack of integrity of budgets for agricultural programmes. In some cases funds are requested for 'research' because of the special appeal of this activity to budget officials but such funds may not be utilised fully or even in large part for research activities but shifted to support of extension and other functions. This diversion of research budgets to non-research activities creates the impression that investments in research do not produce results in keeping with the magnitude of such investments. There must be greater integrity in budget management, especially in organisations where funds for research are embodied with funds for other agricultural development activities.

The benefits from research are not always apparent — certainly not constantly obvious — and research leaders must assume greater responsibility in creating an awareness of the value of research inputs. Dr. Swaminathan emphasised this need for improved communications between research leaders and political-administrative officials.

A number of additional points were emphasised in the discussions on research funding, including the following:

1. There is no substitute for good performance in research which contributes to priority national growth and development, in gaining financial support for research.

2. Key officials in the decision making structure of government, including personnel in the Ministry, planning organisation, and treasury, should be identified and made familiar with research needs and benefits from research.
3. Systematic efforts to acquaint government officials, including members of Congress or Parliament should include periodic reports of research results useful in development, visits to research centres, and special field days to review specific research programmes.
4. Periodic review teams, including both internal and external agricultural research leaders, should assess present capabilities and prospects for improving research resources on a national basis. Reports from such reviews often are most useful in guiding government planners and budget makers.
5. Panels or councils of scientists should be established as advisory bodies for the Ministry and other agencies of government.
6. More attention should be given to development of a public support base through involvement of farmer organisations and trade associations, or the participation in research planning by advisory committees of farmer and industry representatives. The development of an appreciation of the value of research by such 'constituents' furnishes one effective means for stabilising research budgets and adds influential voices in presenting new critical research needs to political and administrative decision makers. This role is now filled in some developing countries by external organisations, including private foundations and other technical assistance agencies.
7. Programme and performance budgetting should be utilised to define specific research needs and to assess — at least in a general way — the costs and returns of different research programmes.
8. Provision should be made for special grant funds, to support scientists or institutions outside of the regular agricultural research system, to provide an added dimension by tapping special talents or facilities in these outside institutions. Such grant funds, however, must be managed carefully to avoid excessive fragmentation and the allocation of resources to low priority studies.

RESEARCH ADMINISTRATION

The primary objective of a research institution is to achieve the maximum output of new knowledge and materials from the usually limited resources of trained manpower, laboratories, field stations and equipment at hand. Applying the usual administrative procedures of government, which are designed largely to 'manage and control' various functions, restricts such output and reduces efficiency in use of research resources.

For research, as for most other activities directed toward fostering growth and economic development, the functions of budget planning, fiscal management, personnel recruitment and management, and provision of equipment, supplies and materials must be regarded as 'administrative services' to facilitate the performance of research.

It is desirable for the Director or Head of a research organisation to be a trained scientist, with sufficient working experience to appreciate the importance of timeliness in availability of equipment, supplies and materials, and of expediting other supporting services for research.

The mobility of research workers, including travel away from their headquarters stations throughout the regions of the country for which they have research responsibilities, must be facilitated through processes permitting prompt decisions on approval of travel.

Travel internationally by scientists is increasingly important to insure continuous awareness of scientific advances which are occurring rapidly throughout the world. Personal contacts at international conferences or seminars are especially significant since communications through journals and publications involve an excessive time lag in conveying research information.

More attention should be given to development of library resources and to the more expeditious retrieval and dissemination of current research information. Such information services must be designed not only for better communication between scientists but also between scientists and extension workers or others concerned with agricultural development.

AUTONOMY

It is difficult to achieve or maintain the flexibility required for effective operation of research through modification of regular government procedures. Such flexibility usually can be provided only through establishing autonomous or semi-autonomous institutions for research.

While it is important to furnish a degree of autonomy for a total national research system it is equally important to avoid excessive fragmentation through the establishment of separate research units for different commodity or problem fields. This is a serious limitation in the development of integrated research capabilities in some countries, particularly in Indonesia and the Philippines as reported in this seminar.

Similarly, an excessive degree of autonomy for research must be avoided since research must remain responsive to the various priority needs for new technology in agricultural development and must be closely allied to companion programmes in extension, marketing, credit, and other aspects of development.

One strong argument for setting up research and other development-fostering functions in extra-governmental or semi-autonomous bodies is that this is frequently the most effective way to break out of the excessively restrictive administrative habits inherited from colonial experience in which 'administration' was usually geared to control or management rather than to growth and development. The setting up of the special organisational structure in the Philippines as described by Secretary Tanco to boost rice production furnishes an opportunity to determine which functions or operations should be revised and institutionalised and which should be maintained as a more fluid part of a total agricultural development system.

It is recognised that the setting up of an excessive number of autonomous bodies within the total government structure presents some problems of organisation and management. Such problems, however, must be weighed against the benefits of insuring responsiveness of research to meet critical priority problems and to furnish a steady flow of essential new technology for development.

SEQUENTIAL DEVELOPMENT

The seminar considered the sequence or order in which the major components of national research organisations, including (1) facilities, (2) manpower, (3) organisational structure, and (4) funds, should be provided.

All countries have some research resource and none are building from anew. A major question is the process by which existing resources can be integrated and consolidated into a reasonably well coordinated system upon which more effective research capabilities can be developed. The experience in Indonesia, Malaysia and the Philippines in drawing together present research resources provides several interesting 'workshops' for the region.

Facilities

Trained manpower cannot be utilised effectively in most agricultural research which requires field stations, laboratories or specialised equipment unless minimum — and reasonably adequate — levels of such research facilities are available. Since research results suitable for reliable recommendations must be developed under conditions which are well known and understood as regards soils, climatic variables, etc., the importance of stabilised field facilities must be recognised. Effective data cannot be gathered from a series of demonstration trials shifting from one site to another over a period of years.

Research facilities, particularly experimental lands, are generally inadequate in the developing countries of Asia from the standpoint of land area, location, or distribution of stations to furnish a reasonable sample of different agricultural evironments over the country. A special problem arises from the tendency to 'integrate' combinations of agricultural development functions which has resulted in some countries in the allocation of former research station areas to schools of agriculture, mechanisation training centres, and extension demonstration centres, with the end result that the research station base is badly 'disintegrated'.

In general, it is desirable to give priority attention to development of facilities because without a place to carry out research neither the indigenous scientific staff nor potential external technical assistance can be utilised.

Manpower

The limited number of well trained and experienced research workers is a generally acknowledged principal restraint to improving research capabilities in nearly all countries of Asia. One exception may be India where the recently established agricultural universities and the Post Graduate School of the Indian Agricultural Research Institute are turning out a steady flow of trained personnel.

The development of a productive research scientist is a long-term process. The combination of advanced-degree training and effective work experience may well require 5 to 8 years beyond the basic degree.

Research manpower development should be planned and budgeted as an integral part of a research system building programme. It cannot, as is now too frequently the case, be left to an uncoordinated collection of fellowships or training awards provided largely by external technical assistance organisations.

Organisational Structure

The organisational structure is important to the extent that there is a sufficient 'institutional base' for the budgeting, planning, conducting, and reporting of research in a systematic manner. The organisational structure need not be complex, but it should be sufficient to insure the continuity, stability and flexibility required for effective research output.

Emphasis should be placed on the substance of research and the implementation of priority research projects, avoiding excessive attention to form of organisation or institutional structure. In order to establish a working pattern for an inter-disciplinary, problem-oriented research system one or two projects should be initiated within the existing facilities available from research stations, universities, private estates, etc. This was most effective in modifying the national research organisation in India and is being utilised alsoin Indonesia to furnish experience in inter-disciplinary research on a priority programme of national scope.

Funds

The funding of research encounters most of the same problems involved in provision of financial support for many other functions requiring government support. Within such common restraints it is important that research budgets be sufficiently flexible to provide for expanding needs for staff, equipment, materials and other operating expenses, and for capital development, consistent with the progressive developing of the national institutional structure. Since operational funds are fitted to requirements of manpower and facilities, such resources must be available or in prospect before firm budgets can be established.

It was the consensus of the Seminar that it is not feasible to assign specific priorities for development of facilities, manpower, an organisational structure or level of funding, since all of these factors are highly important and must be phased and integrated in the development of a national research capability.

Highlights of the Seminar

A. T. MOSHER
President, Agricultural Development Council, Inc.

Two features of the seminar are pertinent to the nature of this summary of its highlights. First, this has been a general discussion seminar rather than a legislating conference. Second, members of the seminar were invited and have participated in their personal capacities, rather than as representatives of their institutions or governments. Consequently, this summary cannot be more than one person's interpretation of some issues that were raised and discussed.

HISTORICAL DEVELOPMENT AND PRESENT SITUATION

The papers presented at the beginning of the seminar on the agricultural research organisations and activities of individual countries revealed both substantial similarities and significant differences with respect to the historical precedents and the present situation of organisation for agricultural research in the countries from which participants came to take part in the seminar.

Those papers revealed that agricultural research in this part of the world was initially undertaken under colonial rule in India and in Indonesia during the second half of the 19th century. The first research was on important export crops, beginning with sugarcane in Indonesia. Such commodity-oriented research organisations multiplied in number up to the time when there were research institutes with respect to eight commodities in India, seven in the Philippines, six in Indonesia and one each in Malaysia and Thailand. Each of these research organisations was normally supported by a cess on the respective crops exported.

The tendency for research institutes to be established to work exclusively on a single commodity has continued down to the present time. And this tendency has been one of the factors leading to increasing concern about the need to coordinate agricultural research efforts in each country.

Meanwhile, more general agricultural research has become an increasingly important activity of ministries or departments of agriculture. Here the pattern has usually been for research to be undertaken by several different agencies within each ministry or department. At the present time, research is conducted by ten different bureaus in Ceylon, by fifteen separate institutes managed by five different directorates within the Ministry of Agriculture in Indonesia, and by nine different agencies within the Department of Agriculture and Natural Resources of the Philippines.

While the pattern is not consistent in all countries, the general tendency has been for the various governmental research institutes to be organised along crop or disciplinary lines. (The Central Agricultural Research Institute of Ceylon has divisions of agricultural botany, agricultural chemistry, plant pathology, entomology, horticulture, food technology, minor plantation crops, tobacco, soil conservation and statistics). This tendency toward proliferation of governmental research institutes and bureaus is another of the developments leading to an increasing concern in recent years to find an effective pattern for coordinating research efforts.

Different approaches have been undertaken in different countries and at various times to regroup and coordinate these multiform research programmes. India took her first step in this direction with the founding of the Indian Council of Agricultural Research in 1929, but the various commodity committees were not brought under direct control by ICAR until 1965. Korea established its Office of Rural Development in 1962, bringing together the various individual research programmes that had emerged there prior to that date. The Republic of the Philippines established its national Science Development Board, charged with the coordination of all research efforts, but the Board did not have sufficient administrative authority to enable it to carry out this function. Most recently, 1969, Malaysia established the Malaysian Agricultural Research and Development Institute to be responsible for all agricultural research in the country except that on rubber which remains with the Rubber Research Institute. Indonesia is now making an effort to establish the Indonesian Agricultural Research Organisation to furnish the coordinating framework for its many research activities.

Meanwhile, on another front, agricultural colleges and universities have been established in increasing numbers and many of them are now conducting considerable agricultural research. India now has over 100 agricultural colleges and, beginning in the 1950s, has developed a set of new Agricultural Universities with one in each state either already operating or just now being established. There are twenty-two faculties of agriculture in Indonesia, ten major agricultural colleges and universities in the Philippines, with at least ten more colleges of agriculture more recently established, and there are ten colleges of agriculture in Korea.

In many cases the colleges and universities now have more personnel with postgraduate research training than do the research institutes in their respective countries. This is particularly true in Korea and in the Philippines. Increasingly, colleges and universities are being integrated in various ways into national programmes of agricultural research in each country.

Country-wide coordinated crop programmes have been both a tool to achieve coordination and a method of operation made possible through the establishing of national coordinating agencies. India now has coordinated national programmes with respect to rice, wheat, corn, sorghum and certain other crops. The Philippines has developed national coordinated rice and corn programmes, and other examples have been cited from other countries.

A relatively new development has been the research programmes launched by private business firms, particularly by companies supplying farm inputs.

The present situation growing out of all of these developments appears to have the following general characteristics:

First, there is a considerable amount of agricultural research currently being carried on in each country.

Second, this research is conducted by a great many different organisations, both public and private.

Third, those interested in agricultural research in each country are searching for ways to coordinate all of their efforts in order to increase their effectiveness.

Fourth, additional concerns have to do with the inadequate number of trained research workers, the organisational pattern of individual research agencies, ways to increase the relevance of agricultural research to national needs, and ways for improving the coordination of research and extension activities.

THE ROLE OF INTERNATIONAL RESEARCH INSTITUTES

While the major concern in this seminar has been about national agricultural research systems, the recently established international research centres are widely recognised to have made great contributions, and to comprise an asset on which all individual countries may draw. There has been general agreement throughout the seminar that while the international institutes have been of inestimable value they do not obviate the need for development of strong national research systems.

The reports on the national rice research projects in the several countries in Asia, together with the subsequent discussions, have reflected the widespread appreciation of the role of the IRRI during the past decade. There is a similar appreciation of the outstanding contribution from the international wheat research programme under Dr. Borlaug's leadership.

The international research institutes are *working organisations* which carry on problem-oriented, inter-disciplinary basic and applied research to provide materials and information designed specifically to fit the agricultural environments of the region. In this respect they differ from many other international programmes which tend only 'to make available' germ plasm materials, or information and resources developed largely under temperate zone conditions. The following functions and contributions of the international research institutes would appear to be of special significance:

1) Development of high-yielding, disease-resistant, widely-adapted varieties.
2) Distribution of hybrid combinations and promising selections, and the maintenance of germ plasm collections.
3) Provision of special collections of varieties and selections as 'uniform nurseries' for testing for disease and pest resistance, quality, and adaptation throughout the region, and the analysis of the resulting data.
4) Development of improved materials and information for crop production, agronomic practices, fertiliser use, disease and pest control, weed control, and other factors involved in 'improved packages of practices'.
5) Consultation by research workers from the international centres in planning and conducting national research projects.
6) Provision of research specialists in residence on a full time basis to cooperate in planning and conducting nationally coordinated research on particular crops. Such personnel have been supplied for research on rice in Indonesia, India, Thailand and Pakistan and on wheat in India and Pakistan.
7) Organising workshops and seminars on selected problems which permit specialists from different countries to interchange ideas and to become acquainted with the most recent scientific advances.

8) Training of research workers, supporting staff, and extension personnel.
9) Providing a focal point or 'clearing house' for combining donor technical assistance resources with those of individual countries.

NATIONAL 'SYSTEMS' OF AGRICULTURAL RESEARCH

While the focus of the discussion throughout the seminar has been on the development of appropriate national agricultural research systems no attempt has been made to outline any 'ideal' structure for a national research system. Instead, we have devoted our attention to a large number of existing national programmes which suggest various ways in which research can be organised to fit the varying needs of individual countries.

It should be possible for research leaders in the different countries to utilise the patterns for research as presented for rice, wheat, maize, land and water, soils, crop diseases and pests, and agronomic experiments to design effective national research programmes in these fields.

It seems in line with our discussions to infer that by a national agricultural research system we do not mean a single monolithic national research organisation. At various points in the discussion, the advantage of having a number of different organisations engaged in research, each with considerable initiative as to what projects it undertakes, has been emphasised. Moreover, I believe we are all in agreement that the research undertaken by private business firms should be considered as part of each national system, although it obviously is conducted by separate organisations. Consequently, it seems clear that a national research system may be composed of:

1) National governmental research organisations
2) State or regional governmental research organisations
3) Agricultural and general college and universities
4) Private sector research organisations

Moreover, the research conducted within such a system might be of many types, including:

1) Research conducted in individual central and/or regional research institutes, universities, etc.
2) Coordinated research projects utilising the resources of several institutes or stations
3) Discreet research projects on widely differing topics related to agricultural production, marketing or policy.

One problem is how to delineate the most effective role for each of these types of organisation, and how to establish productive linkages among them.

GENERAL REQUIREMENTS

One can draw together from various parts of our discussion a considerable amount of agreement on major general requirements for an effective national research system. It is not possible to list these requirements in any order of priority because all of them seem to be essential.

1) The availability of competent research workers, and personnel policies that facilitate their recruitment and retention. Except perhaps in India, it appears that no country in this part of the world has as many research workers with post-graduate training and research experience as would be needed for an agricultural research programme commensurate with the country's needs.

2) Good experiment station organisation and operation. This must include an efficient layout of experimental plots and irrigation and drainage facilities with sufficient uniformity that valid experimentation is possible. It must include precision field and laboratory operations. One participant pointed out that research workers will stand many frustrations, but that they will not tolerate either (a) failure to get credit for what they do, or (b) professional failure in the field due to a lack of the physical facilities and operating procedures essential to valid experimentation.

3) Adequate research equipment and operating funds for each of the organisations or units involved.

4) Interdisciplinary cooperation on complex, problem-oriented projects.

5) Imaginative and competent research administration.

6) Effective cooperation among governmental, university and private sector research.

7) Positive support by (a) political leaders, (b) farmer groups, and (c) the general public, in order that appropriations may be adequate.

8) Flexibility in budgetary planning and expenditures.

MAJOR PROBLEM AREAS IN WHICH DUE CONSIDERATION MUST BE GIVEN TO COMPETING OBJECTIVES

There are problems in conducting effective research where a choice cannot be made one way or the other, but where consideration must be given to two or more competing objectives.

First, it is necessary to achieve a productive balance between centralised and regional (within the country) research. It is generally agreed that each country requires one central research station where all facilities necessary to high quality research are available. But it is also agreed that much research must be carried on either in branches of the central research station located in major type-of-farming areas, or by regional research organisations that may be under either governmental or university auspices. The problem is to get the proper mix of centralised and decentralised research activities.

Second, it is important to achieve a productive balance between coordinated nationwide research schemes, on the one hand, and freedom for individual research stations to select and work on local problems, on the other.

Third, it is important to find an effective balance between research on problems considered by national planners or research administrators to be of high national priority, and projects that may be recognised as important — with high future payoff potential — by individual researchers, even though the latter projects do not at the moment rate high in national priorities.

Fourth, it is important to establish a workable combination of administrative autonomy for research as such, and of coordination of research with other agricultural development activities. The recent trend in most countries seems to be in the direction of setting up largely autonomous research organisations outside of ministries of agriculture or with loose linkages with the ministries. This decision is usually based on the argument that only in this way can research be freed from bureaucratic restrictions that would hamper its rapid development. However, there is increasing concern that this trend may make it more difficult to coordinate research with other agricultural development activities. Several participants expressed the judgment that public agricultural activities other than research also need more operating autonomy and freedom from existing bureaucratic restrictions, and argued that it would be better to keep all public agricultural activities within the ministry of agriculture, give greater operating autonomy to each of them, and revise general operating procedures of the entire ministry in order to allow more effective operations.

Fifth, it is important to utilise the services made available by international research centres fully, without becoming excessively dependent on them.

MAJOR PROBLEM AREAS IN WHICH CHOICES MUST BE MADE

There are other problems with respect to national research systems where certain choices must be made that are mutually exclusive.

Research organisations can be set up to deal with a single crop or with several crops of importance in the country. It was suggested that the single crop research organisation may be more appropriate for international institutes and for producer-financed research on plantation crops than for publicly financed national or regional programmes. In the development of a national research system it is expected that the research programme would embrace such commodity-oriented and non-commodity research problems as required to serve national development objectives. Some programmes may be established on a commodity basis, others may have a broader scope; or some may be confined to individual scientific disciplines such as plant pathology, entomology, soils, etc.

A second problem of this type is how to coordinate and integrate biological, physical and socio-economic research related to agriculture. It was generally agreed that in most countries provision for socio-economic research is inadequate. Some of such research should give attention to problems that are largely economic, but much of it needs to be integrally combined with biological and engineering research in the same projects. As such research is developed the question arises as to whether it should be handled in separate social and economic research organisations, or whether social scientists should be scattered throughout all research organisations related to agriculture. Coordinating and integrating biological, physical and socio-economic research constitutes a problem no matter which of these choices is made.

Arrangements for relating research effectively to 1) planning, 2) extension and 3) the training of research workers constitute another major problem area. Each of these linkages presents its own problems. Those who do the planning need access to research bearing on many of the problems they face. Should planning commissions undertake this research themselves or rely on research organisations to do it for them? Should extension activities be conducted by the same organisation that does research? Should research institutes rely exclusively on universities to train research workers, or should a training component be built into many research projects conducted by specifically research institutions? All of these questions have been discussed during the seminar, but they deserve further, and continuing, consideration.

Finally, a decision must be made as to whether to locate the administration or coordination of the national research system within the ministry of agriculture or outside it. Some of the considerations that need to be taken into account in making this decision are 1) the need of research for administrative autonomy, 2) the need for adequate salary scales and procedures for the selection and advancement of personnel, 3) arrangements for coordination between research and other agricultural development activities, and 4) developing cooperative working relationships between public and privately financed research.

IMPORTANT QUESTIONS REQUIRING FURTHER CONSIDERATION

It is not possible in a conference of 4 or 5 days, in which a major part of the time is devoted to assessing present research programmes and organisations, to come to grips with all critical factors important in strengthening national research systems. A number of items of 'unfinished business' at the end of this week should be noted for further consideration. Some of these have been touched upon but not adequately in our discussions.

Autonomy

The degree of autonomy for research — or for other agencies involved in agricultural development — is a matter of continuing concern. There is no standard pattern or formula for 'autonomy' and conditions within each country will determine the organisational structure. It is important, however, to temper possible over-enthusiasm for autonomy for research with due attention to effective linkages with other development agencies.

Research Priorities

One of the more critical questions confronting developing nations is the allocation of scarce resources to competing development functions, including research. It is generally agreed that research must be directed toward those problems which restrict growth, or toward factors which might accelerate the rate of development. Decisions with respect to resource allocation are the responsibility of political and administrative leaders in government.

Research scientists and research administrators also have an important role in identifying or determining priorities since the feasibility of a given programme may well turn on the availability, or potential acquisition, of improved technology. The mechanism for communications from the individual scientist, through his research organisation, and through Ministerial levels to national planning bodies should be improved. This deficiency is, of course, common to most nations.

In addition to improved procedures for establishing priorities there should be provision for 'stabilising' priorities — to avoid pressures for shifts of research efforts and resources to a project of special appeal to a political or administrative official. This diversion away from hard-core priority research is wasteful of limited manpower and too often contributes little to national development objectives.

Governmental Support

As pointed out by Dr. Swaminathan it is important for research leaders to help government officials achieve an improved understanding of the significance of research and of advances in technology. There are various effective ways to present the potential contributions of research in terms of the economic and social benefits

with which political and administrative officials are concerned. The primary responsibility for communicating these values to top government officials rests with research leaders.

Compatibilities in Inter-disciplinary Research

Emphasis has been given in recent years to inter-disciplinary research on critical problems in development. Progress has been made in integrating concurrent attention of plant breeders, pathologists, entomologists and soil scientists in crop improvement programmes as reported in the Seminar. But while the working relationships between biological and physical scientists in coordinated programmes are improving we have not yet provided adequately for satisfactory involvement of economists and other social scientists in most agricultural research programmes. The capabilities in these disciplines must be involved — in the ring and not just at ringside — to insure that economic and social factors are faced as they arise in the complex processes of agricultural growth and modernisation. This multi-disciplinary effort requires effective coordinating leadership or 'orchestration' as several participants have pointed out.

A part of this problem, as pointed out by Raj Krishna, is the building of strong disciplines. We cannot have effective inter-disciplinary efforts unless the component disciplines are well developed and are fully contributing partners.

The functioning of a Research System

The Seminar reviewed existing national research systems and also representative projects or programmes in various problem fields, as components of national systems. These examples of working projects furnish guidance in assembling problem-oriented, multi-disciplinary projects in a wide variety of fields.

More attention should be given to the operation and functioning of a total national research system, particularly to 1) the degree of centralisation of resources or decentralisation to regional stations, 2) the minimum critical mass of research capability for a given location, 3) the linkages between the major research units or programmes within the system, and 4) the interrelations with agencies responsible for extension, credit, and other functions in agricultural development. These factors are complex and comprehensive and deserve continuing attention.

Steps in Strengthening National Capabilities

The building of research capabilities would be relatively simple if we were starting anew. The task, however, is to remodel, change, and strengthen what now exists. This presents the dual challenge of what to do and how to get it done.

The Indian experience in upgrading research and education involves the use of a series of review teams composed of national leaders and external agriculturists. Dr. Pal expressed the view that international collaboration in the evaluation of the problems in research and education has been most helpful in India.

The 'joint review team' approach also has been followed in Indonesia and in Pakistan. The Philippines has under way a research review by a national team supplemented by external consultants. Malaysia also has utilised external experience in an assessment of her national research programmes.

The more critical problem is how to effect the changes or modifications identified in the reviews as desirable to improve the national capabilities. These may

involve reduction in scope of responsibility of present administrative units, the separation of the research function from a presently integrated agricultural programme of a Ministry, or the diminishing of special privileges enjoyed by research workers in already autonomous bodies such as the commodity research institutes.

Malaysia is now engaged in the implementation of the MARDI Act of 1969, authorising the setting up of the Malaysian Agricultural Research and Development Institute on the base of existing research resources. Indonesia is taking steps to put into effect the recommendations of the Joint Review Team of 1969.

The reshaping and strengthening of national research resources is a national responsibility. External consultants can assist in identifying what might be done but the national research, administrative and political leaders must decide how, when, or whether particular changes are to be made.

A major problem in creating an improved national research system is convincing administrative and political leaders who are not scientists of the need for or value of recommended changes. The setting up of the All-India Coordinated Maize Scheme served as a convincing pattern-maker for the re-design of national research programmes in India. Indonesia is setting up the National Coordinated Rice Research Programme to furnish a working example of an integrated multi-disciplinary research effort involving a number of agencies and institutions. When one such programme begins to show results it eases the task of moving toward new approaches in a national research system.

Opportunities for International Research Cooperation

It was noted during our discussions that opportunities for international research cooperation are not limited to the present international research institutes. Various international cooperative instruments have already been set up by several governments in Southeast Asia. The Food and Agriculture Organisation is proposing a programme of international cooperative research involving countries in similar agro-ecological zones. This was discussed at some length and generally approved. In addition, individual governments and research institutes in Asia can initiate international cooperation on other particular topics or types of problems.

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